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A MANUAL OF PHYSICAL THERAPY

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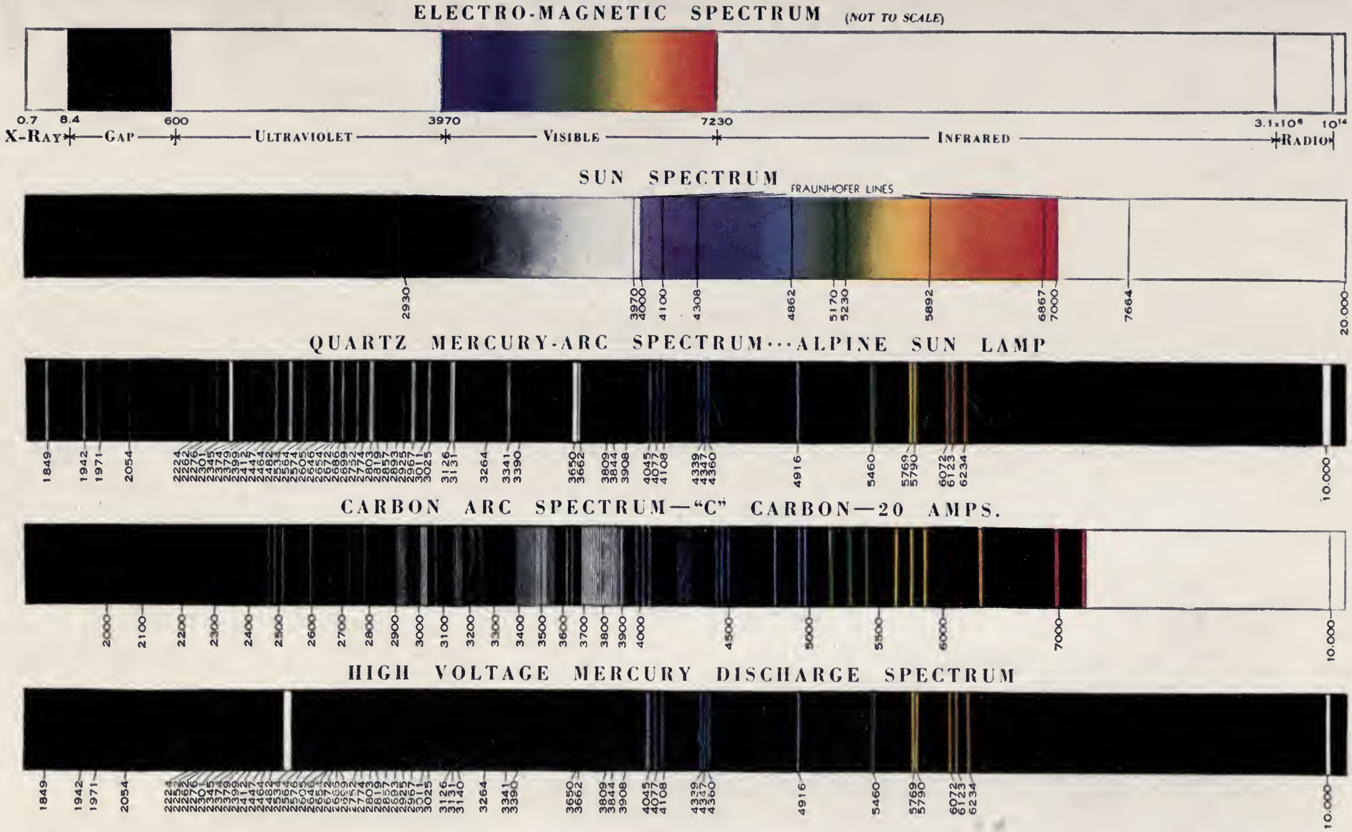

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Comparative Spectra of Principal Sources of Therapeutic Radiation.

ELECTROTHERAPY
AND
LIGHT THERAPY

WITH THE ESSENTIALS OF HYDROTHERAPY AND MECHANOTHERAPY

BY

RICHARD KOVÁCS, M.D.

PROFESSOR OF PHYSICAL THERAPY, NEW YORK POLYCLINIC MEDICAL SCHOOL AND HOSPITAL
ATTENDING PHYSICAL THERAPIST, MANHATTAN STATE, HARLEM VALLEY STATE, COLUMBUS,
AND WEST SIDE HOSPITALS; VISITING PHYSICAL THERAPIST, NEW YORK CITY DEPARTMENT OF CORRECTION HOSPITALS; CONSULTING PHYSICAL THERAPIST, NEW YORK
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PREFACE TO THE FIFTH EDITION

THE five successive editions of this work reflect the steady expansion of the use of physical energies for treatment during the past fifteen years. Its contents are based on the subject matter of the author's instruction courses, given first under the auspices of the Columbia University School of Medicine at the Reconstruction Hospital in New York and since 1927 at the New York Polyclinic Medical School and Hospital. Electrotherapy and light therapy have been always the main forms for office employment of physical treatment agents by physicians because of their fairly simple control and efficiency. ELECTROTHERAPY AND LIGHT THERAPY was written primarily to offer reliable information on the theory and practice of these two important therapeutic agents. The intervening years have brought about the development not only of new phases of the original subject but also a steady increase in the use of treatment procedures by water, exercise and manipulation. Some of these methods require very simple equipment or none at all except the knowledge of how to use them, which makes it possible to give patients their benefit at the bedside as well as in the physician's office. In order to furnish information about these methods, beginning with the fourth edition of this work, the essentials of hydrotherapy and mechanotherapy were included in the presentation.

The story of the progress of "physical medicine" as part of the practice of medicine, in the period of the past twenty-five years during which the author has been actively engaged in it, is an impressive one. In the United States up to the time of the World War I, the few medical men practicing as "electrotherapists" were looked upon by many of their medical brethren with suspicion, mingled with pity. Hydrotherapy, manipulation and massage were mostly exploited by poorly educated technicians. Generally speaking, there were no physical therapy departments in hospitals where the different physical methods could be correlated as part of a general therapeutic scheme and where clinical and laboratory research could be carried on. This situation first changed for the better during and after World War I, by the creation of broadly conceived physical treatment departments in order to benefit those injured and disabled in that war. In these departments all the time-honored and many of the new methods of physical therapy were practiced under the watchful eyes of competent medical men. After the War there became available a large body of competent technicians and a number of physicians who continued their work in civilian practice and under this impetus, development of many new and efficient physical therapy methods took place. Groups of medical men and technicians organized for mutual coöperation and study and the medical profession at large showed much interest in physical therapy. The American Medical Association created in 1927 a Council of Physical Therapy which became a potent factor in disseminating proper information, in advocating basic training in physical therapy, and in curbing unwarranted claims and commercialization. As a result of all these factors, in the years up to World War II there was constant progress in education, research, and in the development of new methods and the expansion of clinical application of physical therapy. The lines of demarcation between physical therapy that can be effectively carried on by general practitioners, by specialists in various departments of medicine and by specialists in "physical medicine" became gradually established.

World War II thus found physical therapy ready for further expansion and for its fullest utilization for the benefit of war casualties. No wonder that the number of physical therapy departments and training centers in Army and Navy hospitals and other service and rehabilitation centers has reached an all time high. The need for caring for the injured, convalescent and those to be rehabilitated has made physical therapy methods the cornerstone of this work and also by practical necessity brought occupational therapy in close correlation to it. All this is likely to continue for many years to come. At the same time, the term Physical Medicine became officially adopted in connection with the greatly increased scope of physical methods for treatment and diagnosis. The American Medical Association, in renaming in 1944 its Council on Physical Therapy the Council on Physical Medicine, stated: "Physical medicine includes the employment of the physical and other effective properties of light, heat, cold, water, electricity, massage, manipulation, exercise and mechanical devices for physical and occupational therapy in the diagnosis and treatment of disease." In the same year a great American citizen and humanitarian appointed the Baruch Committee on Physical Medicine, and after its extensive survey of the needs of this branch of medicine he donated a fund of over a million dollars to carry out the most urgent educational and research requirements. Simultaneously, the National Research Council and the National Foundation for Infantile Paralysis also made grants for research in physical medicine. As a result of all these new developments, prospects for large scale increase in instruction, research and clinical application of physical medicine in the near future are indeed bright.

In the fifth edition of this work a concise presentation of all present day phases of physical medicine is offered, while special emphasis on electrotherapy and light therapy is being retained.

In this volume the newer uses and methods of electronics, of electrodiagnosis, of ion transfer, and of ultraviolet radiation have been incorporated; the chapter on exercise has been considerably enlarged; a new chapter on hypothermy has been added, and a revised glossary inserted, pertaining to definitions of electrotherapy and light therapy as well as to muscle and nerve action, and mechanotherapy. All chapters in the general as well as in the special part have been brought up to date. Eighty-seven new illustrations were added and 49 obsolete ones omitted.

The author is deeply grateful to many medical friends for their collaboration. Drs. R. V. Gorsch (now serving as Colonel in the U. S. Army), W. W. Morrison (now serving as Commander in the U. S. Navy), and Dr. Hans Behrend have revised their special chapters. Dr. F. W. Ewerhardt contributed to the Glossary, Dr. Arthur L. Watkins to the chapter on Electrodiagnosis, Dr. Jerome Weiss reviewed the chapters on physics and Dr. Robert Schlesinger again skillfully furnished a number of schematic drawings. A number of authors permitted reproductions of their illustrations and the educational and technical departments of the electromedical industry again assisted in furnishing technical data and illustrations. Due credit for all these contributions appears in the text.

The publishers were again most liberal and coöperative in producing a volume profusely illustrated and typographically excellent.

R. K.

New York City

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ELECTROTHERAPY AND LIGHT THERAPY

CHAPTER I

INTRODUCTION

PHYSICAL THERAPY IN THE PRACTICE OF MEDICINE

Physical forces furnish the basis of all life on earth. The warming rays of the sun, the flow of water, the electrical charge in some of the bodies around us, all form parts of Nature's inexhaustible and all-powerful array of forces. The same physical forces if properly mastered are of inestimable value in the art of healing. They may help to increase circulation, enhance local and general body metabolism, relieve nerve irritation or stimulate nerve function, inhibit growth of germs or destroy them altogether. As a result of all these effects, physical agents may speed up repair of injured or diseased tissues, restore disturbed function, relieve pain and improve the condition of the entire body.

Basis of Physical Therapy.—The human body is a complex transformer of energy. Chemical energy stored up in food or in drugs is split into component molecules and serves to keep up or modify physiological functions in the body. Some of these chemical processes create physical energy—such as heat, electrical action currents—either as a by-product or as an essential object. Physical energy can also be conveyed to the body from the outside by various methods and thus serves to stimulate physiological processes. Any form of physical energy applied to the human tissues exerts a primary physical or physico-chemical action and this in turn affects cellular activity. These "secondary" physiological effects serve to influence a pathological condition either locally or systemically and thus create therapeutic effects.

Most of the procedures and effects of physical measures are applied through the skin. The skin is not merely a protective covering of the body but also a complex structure of perception, absorption and excretion. It is capable of a variety of reactions to stimuli from the outside and from within. Most of the reactions brought about by physical forces are non-specific in character. It has been shown that stimuli of different nature, such as heat, manipulation, chemical or electrical agents may cause similar vascular response in the skin, consisting of dilatation of blood-vessels, increased permeability of the vessel walls and increased circulation.

The nervous reflex effect of "counter-irritation" through the skin upon deeper parts may be alike and this explains the seeming paradox of similar therapeutic effects on painful conditions by physical agents of apparently different nature. There are definite reflex reactions between certain cutaneous areas and the gastro-intestinal tract. In general, internal organs are reflexly related to the skin directly overlying them, and the effect produced by reflex is the same as that seen in the cutaneous area treated. Cold applications to the cutaneous area produce a related effect on the organ beneath, *i. e.*, a tonic or stimulating procedure. Applications of heat cause relaxation, increased blood supply and increased activity. (Fig. 1.) Many visceral disorders, particularly disorders of the gastro-intestinal canal, may be beneficially influenced by appropriate stimulation of the corresponding cutaneous areas. There are, on the other hand, specific reactions in the skin, such as those caused by ultraviolet radiation, which cannot be produced by any other agency. With physical agents capable of penetrating the protective covering of the skin and other tissues, specific effects on inner organs can be expected. This part of physical medicine offers at present a large field for clinical research.

TABLE 1.—PRINCIPAL PHYSICAL AGENTS AND SOME OF THEIR EFFECTS

Physical agent	Primary physical effect	Secondary physiological effects
Hot water Hot air Radiant heaters Incandescent lamps Diathermy Sun	Thermal	Hyperemia Sedation of sensory or motor irritation Attenuation of germs
Sun Heated metals Carbon arc Mercury vapor arc	Photochemical	Erythema Pigmentation Activation of ergosterol Effects on blood
Roentgen-ray Radium	Physicochemical	Contraction of tissues Molecular disintegration
Galvanic current	Electrochemical	Polar; vasomotor stimulation Interpolar: metabolic
Low frequency, interrupted and alternating currents	Electrokinetic	Muscle stimulation Increase of venous and lymph flow, stretching of tissue, reflex stimulation
Vibration Massage	Kinetic	

The strength, duration and extent of application determine the local or general sedative, stimulative or destructive effects of any physical agent.

It is evident that a definite diagnosis arrived at by all known methods, or at least an acceptable working diagnosis, is essential before any form of therapeutics is instituted. If physical treatment is being considered, either as a primary line of attack, or as an adjunct to other appropriate treatment, the question should not be "What kind of apparatus shall be applied?" The query should be rather: "What type of physical agent, or combination of agents, will be best suited to overcome the anatomical or functional disorders in this individual patient?" We must strenuously resist the conception fostered by commercial interests that, for treating a given condition, a certain make of apparatus is necessary.

The object of physical therapy is the bringing about of certain physiological responses and the student of this branch of therapeutics must learn to choose from the available methods, according to the circumstances. He should have no difficulty to make his choice once he had sufficient theoretical grounding and acquired clinical experience under competent guidance.

For the efficient and safe application of any physical measure, the following basic knowledge is essential:

1. What is the physical nature of the form of energy employed?

2. What are its primary physical, and its secondary physiological, effects on the body?
3. In what pathological or functional changes does it prove clinically useful?
4. What is the correct technique of its employment?
5. What are its possible dangers and contraindications?

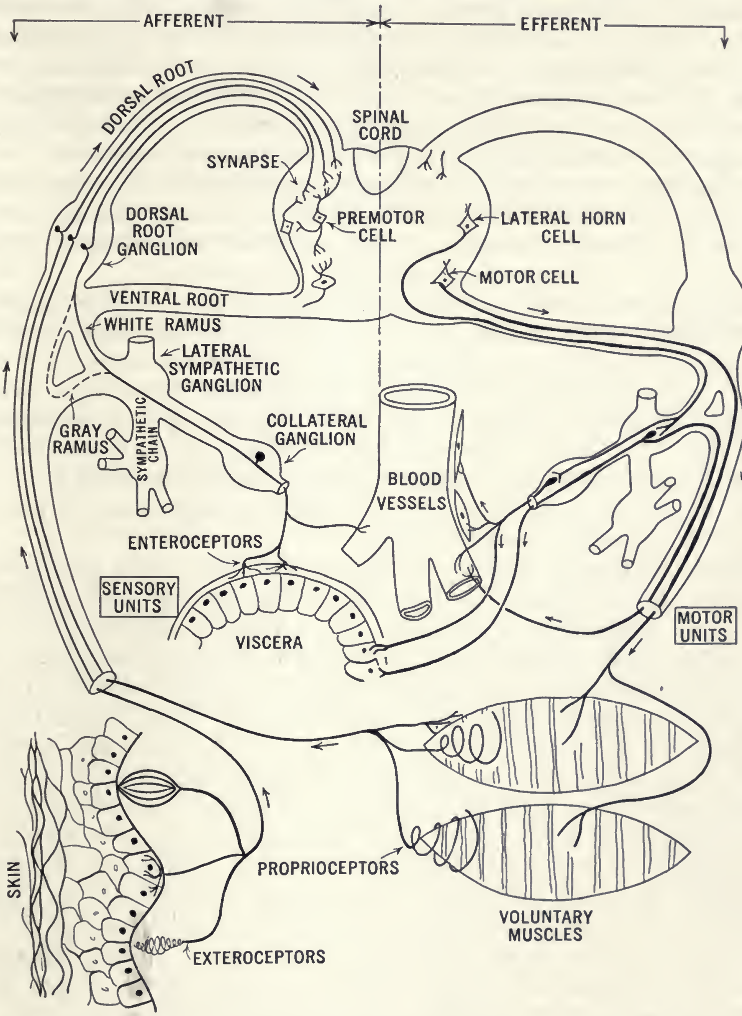

FIG. 1.—Schematic diagram to illustrate the interrelation of vasomotor, secretory and myotonic phenomena caused by sensory stimulation through the reflex arc. Afferent pathways on the left, efferent pathways on the right. It can thus be seen how radiant heat on the skin surface can cause reflex vasodilatation of deeper structures and change in muscle tone. Also it is apparent how visceral stimuli can elicit muscle spasm and referred pain. (After Wiggers.)

It is evident that any physical measure capable of doing good is also capable of doing harm if it is incorrectly applied. Likewise there is a threshold of intensity and duration where therapeutic efficiency begins; and there is a danger zone when that threshold is exceeded. The quantitative or measured conception of physico-physiological effects is established by painstaking clinical and laboratory research work and is the main factor in gradually elevating physical therapy procedures from an empirical stage to that of a well-defined scientific procedure.

Scope of Physical Therapy.—A frequent objection voiced by the uninformed is that physical therapists concern themselves with all too many pathological conditions, instead of remaining within a well-circumscribed domain. No such objection is voiced against the similar wide use of drug therapy in all departments of medicine. Sollman[1] states, "Although drug therapy and drugless therapy may seem direct antipodes to the superficial thinker, they involve the same principles, evoke the same phenomena, accomplish the same results. They differ only in the means which they employ, of which sometimes the one, sometimes the other is better adapted to secure the desired end. Indeed, the differences between physical therapy and pharmaco-chemical therapy are no greater than those between radiant and direct heat, or between local and general anesthetics."

Physical therapy is neither a causal nor a specific therapy in the majority of conditions. It serves in acute disease conditions to relieve symptoms and speed up recovery. Simple thermal and hydriatic measures have been part of standard nursing procedures for a long time. In local and general infections, ultraviolet radiation and heat measures are of considerable importance. In certain acute systemic infections such as gonorrhea and its complications and a few others, artificial fever therapy has an almost specific effect. In acute traumatism, the efficient application of physical measures is essential for early recovery.

The most important field for physical therapy lies in the treatment of chronic disease conditions. In these, physical agents are quite dependable and safe for relieving pain and offer often a definite chance for recovery by bringing about gradual resolution of chronic inflammatory processes. General thermal or hydriatic agents acting through the skin as an organ will stimulate general circulation and elimination. Local thermal agents can stimulate the function of any organ or body region and speed up absorption of products of inflammation or trauma. Mechanical, electrical and photochemical stimuli can promote local chemical interchange which in turn affects the whole system; they also may act by active exercise or nerve reflex upon deeper situated parts or organs. Ultraviolet irradiation is a specific treatment for rickets. High-frequency electricity and surgical galvanism are valuable methods for the destruction of minor new-growths and diseased tissue; major electrosurgery has made possible important advances in surgical technique. Among the many conditions in which physical measures prove of definite value are traumatism, both acute and chronic; the various forms of arthritis and the rheumatic states, many kinds of paralysis and other organic and functional affections of the nervous system, chronic digestive disturbances, chronic diseases of the heart and blood-vessels, acute and chronic inflammatory conditions of the genital organs, nose and throat and many skin lesions. There are some obvious advantages in employing physical remedies. Usually they can be directly applied to the affected parts and in acute conditions, as a rule, they give immediate relief. In chronic conditions, patient and systematic application is essential, but there is no danger of habit-forming as is the case in the use of certain drugs. In some instances physical measures will enable the clearing up of lesions apparently requiring an operation.

Place of Physical Therapy.—Physical therapy is not a new system for recognizing and treating disease. It rightfully forms part of the practice of medicine and will be of most value in the treatment of disease and injury when employed by or under the immediate supervision of the physician who has learned why there is a scientific basis for the use of some physical energy or its combination with others and who knows when and how to apply it. Physical therapy cannot be practiced apart from general medicine and surgery, for it must be applied with a broad knowledge of clinical diagnosis. As a matter of fact its methods serve as a diagnostic aid in a number of conditions; hence its newer designation as physical medicine. Conversely medicine and surgery should not be practiced without physical therapy, a valuable adjunct, when coördinated with other indicated therapeutic measures, and, at times, a primary method of treatment.

There is ample need and opportunity for the systematic use of physical measures by all medical men. However, the best interests of patients will be most satisfactorily secured if the possibilities and limitations of each group of physicians employing physical therapy are clearly understood. The general practitioner should be able to utilize simple thermal and hydriatic measures both at his office and at the bedside, and should be able to prescribe and demonstrate exercise for traumatic, arthritic, and other every-day conditions. He should employ elaborate pieces of equipment only after he has had competent clinical instruction in their use. Specialists in various fields of medicine, such as surgery, orthopedics, gynecology, and nose and throat diseases will all derive great satisfaction from such physical measures as are applicable to their respective fields, once they have had proper theoretical grounding, and at least the rudiments of clinical training in their employment. There is need in every large center of population, and certainly in all large hospitals, for medical men with special training in general physical therapy to be able to render service with all modern resources, such as fever therapy, under-water exercise, and the various electric and light treatments. It requires training and aptitude, as well as official support, to carry on clinical and experimental research work, and to check on the claims for the ever-increasing number of new devices. Properly trained technicians are indispensable for administering physical therapy in institutions, and in most physicians' offices. But it is not fair to expect technical aides who have been trained to employ physical measures only according to instruction, to be responsible for the ordering of treatments, and the judging of their efficiency. This will be the case if a department is only nominally in charge of a physician or a group of physicians who have neither special interest nor training in the subject. No fountain can rise above its source and no physical therapy department can render the best possible service unless it is headed by a physician thoroughly familiar with the methods and scope of modern physical treatment.

Classification of Physical Therapy Methods.—The classification of the various physical measures is a somewhat involved problem for no matter on what basis it is done, there will be overlapping, For didactic purposes and for institutional classification, heading under each physical agent—

such as electrotherapy, hydrotherapy, etc., as shown in Table 2—has proven practical. In such a classification the same agent, according to its form of application, may exert a variety of physical and physiological effects. For an intelligent conception of basic effects and prescribing, a grouping of physical measures according to the primary thermal, mechanical or chemical effect is more desirable, as has been shown in Table 1. This brings together physical agents of a different nature—electricity, water, light—but shows that their physiological effect is based on a similar primary physical effect.

TABLE 2.—METHODS OF PHYSICAL MEDICINE

1. Electrotherapy
    - Galvanic or direct current—Electrophoresis
    - Low-frequency currents—Electrodiagnosis
    - High-frequency currents—Electrosurgery
    - Static electricity
2. Light therapy
    - Photothermal radiations—Visible and infrared rays
    - Photochemical radiations—Ultraviolet rays
    - Heliotherapy
3. Hydrotherapy
    - Hydrothermal measures
    - Hydrokinetic measures
4. Hyperthermy and Hypothermy
5. Mechanotherapy
    - Massage and manipulation
    - Medical gymnastics
    - Occupational therapy

Roentgen-ray or roentgen therapy although employing an agent of physical nature does not appear in the above classification because by well-established custom it forms part of another large special field of medicine.

Apparatus for Physical Therapy.—It is by no means necessary to possess a large array of machinery to produce the few basic physical and physiological effects: Simple hot and cold applications, active and passive exercise can do a world of good by themselves. There is danger in too much and too complicated apparatus for therapy, just as there is danger of too much apparatus for diagnostic purposes when one's five senses and clinical experience, unaided should be adequate to solve many problems.

On the other hand, modern mechanical and electrical progress offers many types of efficient apparatus, with the saving of expenditure of one's own energy, of time in accomplishing results, and with the possibility of accurate dosage and location of the physical energy to be applied.

The advantages of modern electrical apparatus over some of the older crude methods are just as evident as those of the modern methods of transportation over the time-honored mode of walking and pushcarts. Those who grudgingly admit that they believe in massage and exercise, but do not care three figs for all this apparatus, the glittering machinery of practice, simply handicap themselves very sadly. They limit their speed and confine their radius of action to a narrow segment of what it might be.

For the ever-increasing scope of physical therapy, apparatus is quite indispensable, and will tend to become more so in the future. The finer and more varied the control, the larger the range of power, the more accurate the measurement of energy input, the more varied and the more dependable will be the subsequent physiological and clinical results.

Electrotherapy and Light Therapy.—From the standpoint of the general practitioner, electrotherapy and light therapy open up many new vistas in medicine and surgery and although not entirely replacing some of the simple methods of application of heat, massage and exercise, enable a well-controlled and more extended application of physical energies. With comparatively simple and inexpensive equipment, the general practitioner can produce results in many conditions in which treatment by medication and surgery alone is not quite satisfactory. The rational use of such measures should be part of the office work of most progressive physicians because it increases the efficiency of the medical service rendered.

A striking illustration of the changed conception of the place and future of electrotherapy is contained in an editorial of the New York Times,[2] written apropos the First International Conference of Fever Therapy:

"Twenty-five years ago the physician who clamped a pair of electrodes on a patient and passed an electrical current through the body either to heat tissues according to the principles of diathermy or twitch muscles or stimulate the flagging system was regarded either as a self-deluded enthusiast or as a quack who could not be restrained because he had a license. Now the First International Conference on Fever Therapy is being held under the high patronage of such medical eminences as Nobel Prize winner Wagner-Jauregg, Volhard and Bessemans. No longer is there any doubt about the cures of the electrotherapist. Venereal diseases, general paralysis of the insane, arthritis and a score of other diseases are now treated electrically and successfully without causing the professors in the medical colleges to lift their eyebrows.

"In French a physicist is still called a *physicien*. The justification for doing so is more apparent than ever in these days of waves and high-frequency currents applied in medicine. Many of the men who practice the new electrotherapeutics are so well grounded in physics and electrical engineering that they have made striking technical improvements. This new science needs their combination of electrical and medical knowledge. It still lacks measurements, still lacks standards. But empirical as it still is it supplies evidence that the old pill box is obsolescent. Medicine today belongs to the chemist, the electrotherapist, the bacteriologist, the radiation expert. Gradually it is acquiring the precision that we associate with real science. And the electrotherapists who were once regarded as little better than charlatans helped to bring about the change."

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1. SOLLMAN, J.: Address of Welcome to the 19th Annual Convention of the American Congress of Physical Therapy, Arch. Phys. Ther., **21**, 561, 1940.
2. New York Times, March 31, 1937.

PART I

Electrophysics

CHAPTER II

FUNDAMENTAL ELECTROPHYSICS

The Structure of Matter and the Atomic Theory. The Electron Theory of Matter. Electric Charge. The Elementary Law of Electrophysics. Conductors and Insulators. Transfer of Electrical Charges. Charging by Induction. Condensers. Electric Potential. Static Electricity. Electric Current. Thermal, Electro-magnetic, and Chemical Effects. Electrical Units: the Ampere, the Ohm, the Volt. Difference Between Amperes and Volts. Ohm's Law. The Watt and the Farad. Measuring and Regulating Devices.

No one can apply electrotherapy efficiently and safely unless he is fairly well grounded in the physics of electricity and has acquired practical experience in the therapeutic employment of the various electromedical currents. The physician must be familiar with the every-day use of electricity and the construction and control of every piece of apparatus he employs. It would seem a poor exhibit of efficiency should a busy physician's officework come to a stop while someone scurries around to get an electrician to remedy such common troubles as a blown fuse, or a broken connection in a conducting cord or socket plug.

The Structure of Matter and the Atomic Theory.—The modern theory of the structure of the atom holds that electricity forms an integral part in the structure of all matter. Anything which has weight and occupies space is called matter. Matter is composed of some ninety-two primary substances, known as elements, which cannot be split up into bodies of a different kind without changing their characteristics. Some of these are solids, like zinc, iron, sulphur, others are liquids, like bromine, mercury; finally, some are gases, like hydrogen, oxygen and nitrogen. All complex forms of matter, all minerals, all tissues in animal or vegetable life are formed by the combination of these elementary substances.

It is obvious that, while masses can be split up into smaller and smaller particles, there must be an ultimate particle of any element that cannot be divided, and which forms the basis of the element as a stable unit. According to Dalton's classical theory, proposed in 1802, such a particle is called an *atom* (from the Greek a-tomos: indivisible). The atom, the most minute unit of matter, takes part in chemical changes by uniting either with the other atoms of the same kind to form appreciable quantities (molecules) of the same element or with atoms of other elements to form compounds. A *molecule* may consist of two or more atoms, the atoms being all of the same element—for instance, all hydrogen or all oxygen, or the molecule may consist of different elements—for instance, a molecule of water is composed of 2 atoms of hydrogen and 1 of oxygen (H_2O). The unit of atomic weight is the lightest of atoms, the hydrogen atom.

The Electron Theory of Matter.—Experimenting with electrical discharges from glass tubes having a high degree of exhaustion, J. J. Thomson, later Lord Kelvin, of Cambridge, England, discovered, in 1897, a stream of extremely minute particles projected from the negative electrode or cathode. He proved that the particles forming these "cathode rays" have each a mass amounting to about 1/1800 that of a hydrogen atom and that each carries a negative charge. He named these particles *electrons* (from the Greek elektron: amber, the substance which can be electrified by friction) and Millikan, the American physicist, succeeded in measuring and isolating them.

The electron theory supposes that every atom of matter in the neutral state is made up of a certain number of elementary positive units and an equal number of electrons. The charge on the electron is negative but this is only an accident; the choice of what was to be positive electricity and what negative was originally quite arbitrary and it happens to have made the electron negative. Electrons have become universally accepted as the smallest known particles of matter and have now almost become an article of commerce. In radio tubes electrons are given off as readily as hot water gives off steam.

The electron is the unit of electricity and represents a universal element of structure of all matter, whether flowing along slowly in an electric current or hastening through space at an extremely high rate as a cathode ray, whether it is emitted in radioactive disruption or in a photoelectric process, whether it is "jumping" in our lamps, etc. It is always the same physical unit, proving its identity by exhibiting the same charge and the same mass, in particular by keeping the ratio of charge to mass constant.

Rutherford's experiments with radioactive elements established the second universal constituent of the atom called the *proton*. The proton has an electrical charge of the same value as the electron, though of opposite charge but its mass is quite different, being 1800 times as heavy as that of the electron. Every atom is believed to consist of an extremely small nucleus in which is packed all the positive electricity and around which the negative electrons are arranged in some definite order but with wide spaces between them.

The atoms of all elements are thus believed to contain as constituents both positive and negative electricity. In the hydrogen atom there is only one proton and one electron present, but in all other atoms there are more protons than electrons in the nucleus, which thus possesses a positive charge. This is balanced by the addition of electrons surrounding the nucleus. The atom of oxygen contains sixteen protons and sixteen electrons. (Fig. 2.)

Modern physical research has made numerous new discoveries about the structure of matter. Anderson in 1932 found the *positron* a positively charged, rather unstable elementary particle of the same weight as the electron. Chadwick in the same year discovered the *neutron*, an electrically neutral particle of the same weight as the proton. Research in radiation energy has added another primary constituent of matter, that of the *photon* or light quantum, about which more will be said in Part III. Recent work with atoms through the use of the cyclotron and similar atom smashing devices causes atoms to give up other than *electron* particles; in fact, actually transforming or transmuting the atom to one of a different elemental character. Electrons, protons, neutrons, positrons, dueterons, etc., are all fragments of atomic destruction.

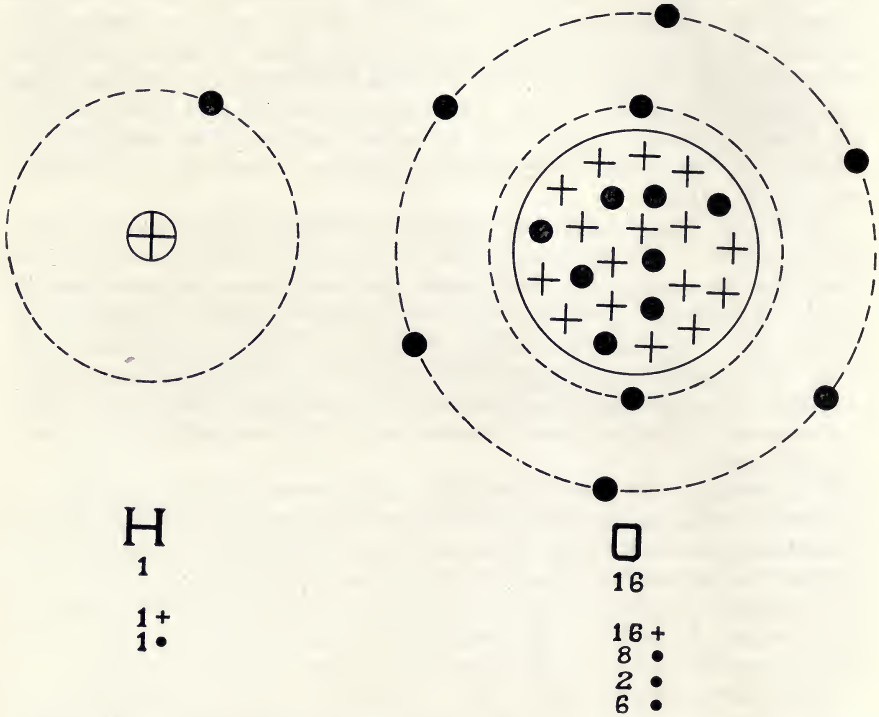

FIG. 2.—Schematic illustration of electron theory. Each atom contains an equal number of protons and electrons. Protons are represented by + sign and electrons by dots. In the hydrogen atom there is only one proton and one electron present, while the oxygen atom contains 16 protons and 16 electrons. (After Gibson.)

Electric Charge.—The electron theory is the basis of explanation of all electrical phenomena. The binding together of electrons and protons into atoms represents large amounts of energy. An object containing a normal balance of electrons and protons shows no electrical properties. If the atomic structure is disturbed by an external force of sufficient strength, such as friction, heat or chemical action some of the electrons of the atoms may be driven away. Charging a body consists of taking away or adding electrons. A *negatively* charged body is one which contains *more* electrons than its normal number; a *positively* charged body is one which contains *less* electrons than its normal number.

The Elementary Law of Electrophysics.—The basic law which underlies all considerations in electrophysics is: bodies charged with the same kind of electricity repel each other while those charged with a different kind of electricity attract each other. In other words, *like charges repel and unlike charges attract.*

For detecting the condition of an electrified body one may use an electroscope, a pith ball hung by a silk thread from a glass support or the well-known gold leaf electroscope, two strips of thin gold leaf attached to an insulated brass rod and hung in a glass jar. (Fig. 3.)

Conductors and Insulators.—Substances which lead off the electric charge quickly are called *conductors;* those which prevent the escape of an electric charge are called non-conductors or *insulators.* Most substances conduct a little and under powerful influence (high voltage currents) any insulator may suffer enough atomic change to permit a flow of electrons, and hence under sufficient electrical stress there is no sharp demarcation between conductors and non-conductors.

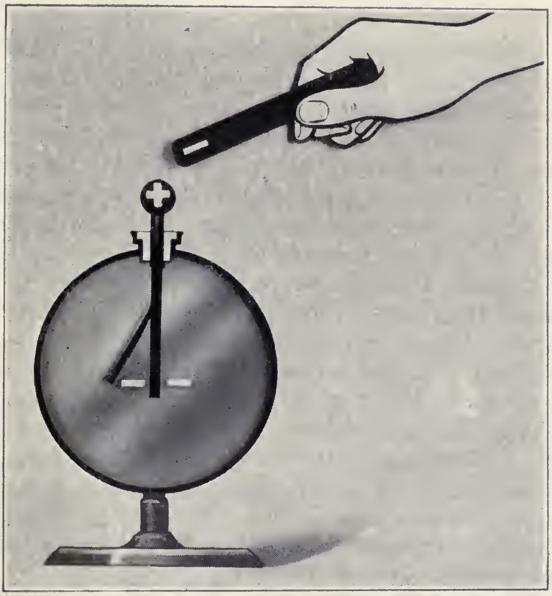

Fig. 3.—Detecting an electric charge. A goldleaf electroscope is charged by approaching it with an electrified vulcanite rod. The negative charges are driven toward the two leaves which show an electric charge by repelling each other.

Metals are the best conductors. In all metallic substances there are always a number of electrons free from their atoms and as soon as these free electrons are pushed along in the conductor, a flow of electricity will begin. The larger the number of free electrons in any substance, the greater will be its conductivity. The substances which are good conductors of electricity are also good conductors of heat. Watery solutions of acids, bases and salts are known as *electrolytes* (from elektron and lutos: soluble) and also conduct well. The difference between metallic and electrolytic conductors is that in the latter a flow of electricity brings about chemical changes.

A substance in which there are no free electrons and the resistance of which to the flow of electricity is high is called an insulator. There are *solid* insulators such as hard rubber, mica, glass, amber, porcelain and silk and *fluid* insulators, such as oils, paraffine and pure distilled water. Lubricating oil placed over parts of electrical apparatus through which the current has to flow will prevent its passage instead of facilitating it. To prevent leakage of electricity electric light wires and terminals of electro-medical apparatus are mounted on glass, porcelain or hard rubber.

Partial conductors are substances which ordinarily resist the flow of electricity but under certain conditions will become conductors.

TABLE 3.—INSULATORS AND CONDUCTORS

Insulators	Partial conductors	Good conductors
Amber	Dry wood	Metals
Glass	Paper	Carbon
Hard rubber	Alcohol	Graphite
Paraffine	Tap water	Watery solution of salts and acids
Dry air	Moist air	Wet wood
Porcelain	Kerosene	
Distilled water		

Important examples of partial conductors are: (1) Distilled water is an insulator, if sufficiently pure, containing no dissociated molecules; as soon as it contains a slight trace of salts, however, electrolytic dissociation takes place and the water becomes a good conductor. Ordinary tap water, always holding an admixture of salts, is therefore considered a partial conductor. (2) The tissues of the human body; they are good conductors on account of their saline ingredients, but the horny substance in the superficial layers of the skin serves as a fairly good insulator. By moistening the surface of the skin we overcome its insulating property. In applying some forms of electricity to the body, part of our technique is directed toward overcoming skin resistance, so as to secure a free passage of current to the well-conducting tissues beneath. In conduction of so-called high-tension or high-voltage forms of electricity skin resistance plays only a minor rôle. (3) Dry air is an insulator, while moist or ionized air is a partial conductor. The high-tension charge of static machines leaks off when the atmosphere is humid, while on dry days the charge is easily retained. Perfect vacuum is an insulator; in the so-called glass vacuum electrodes used in treatment the air is only rarefied, so that they are fairly good conductors of high-tension current.

Transfer of Electrical Charges.—For transferring electrical charges conductors such as wires or metal plates are used; at the same time, these must be insulated from other conductors by non-conducting material, hence the covering of copper conducting wires by an insulating layer of silk or rubber, and the mounting of electrodes on insulating handles. Electricity of high tension, such as the static current or the monoterminal discharge of a high-frequency machine, is difficult to insulate, and its tendency to leak off to a neutral body or the ground in the form of sparks must be guarded against by long insulating handles and by holding it at a safe distance from all grounded objects.

Charging by Contact and by Induction.—This is easily explained by the electron theory. When a positively charged body is brought near an insulated conductor, the free electrons in the conductor are attracted from all parts of the conductor to the end nearest the positively charged body and this end thus becomes negatively charged. As these electrons were drawn away from the far end of the conductor, it has less than its normal number of electrons and is therefore positively charged.

Condensers.—A condenser consists of two opposing surfaces of metal separated by some insulating substance (glass, mica or air) on which electric charges can be collected (or condensed) because the reciprocal attraction across the separating insulation annuls the repulsion. *Capacity* is the relative power of holding the ratio of the electricity held captive to the tension that arises; it depends on the size of the plates, their distance and the kind of insulating substance between them. A *dielectric* (unelectric) substance is one which offers great resistance to the passage of electricity by conduction, but through which electrical force may act by induction.

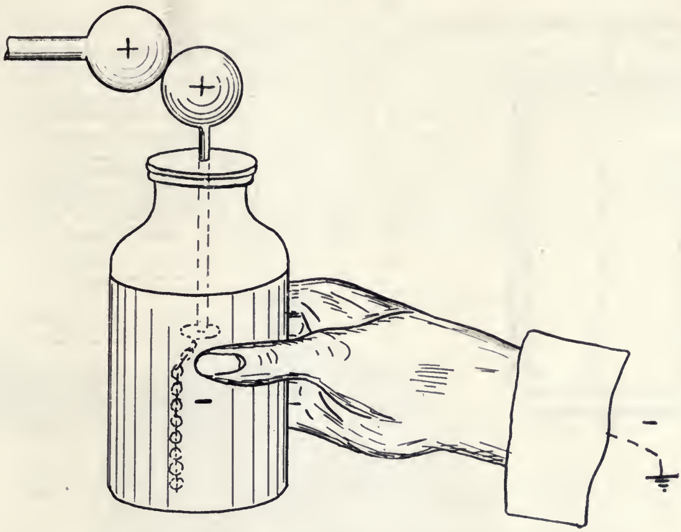

Fig. 4.—Charging by contact. A Leyden jar is held by the hand, and thus grounded; its knob is brought in contact with a source of frictional charge, such as the positive terminal of the static machine; the positive charge on the outer layer will be repelled to the ground and the earth will supply the outer layer with an amount of charge sufficient to counterbalance the charge on the inner layer.

Condensers may be likened to water tanks and are necessary for the holding of a definite amount of electrical energy ready for immediate flow in certain types of apparatus, such as high-frequency machines and electronic devices. If the plates of the condensers are connected, the positive and negative charges are united and the condenser is "discharged." Such

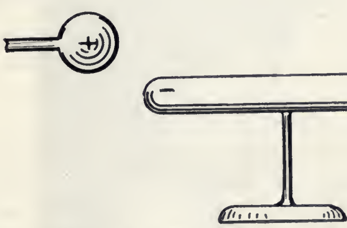

Fig. 5.—Charging by influence or induction. Bringing a charged body near but not in actual contact with an insulated conductor will cause a separation of the electrical charges; the opposite charges are repelled to the far end of the conductors, and if they are led off by another conductor a definite charge is left on the first conductor.

discharge is usually "oscillatory" in the form of electric waves and is accompanied by a sound. (See next chapter.)

The Leyden jar is the earliest and best known form of a condenser and consists of a wide-mouth glass jar coated by a metal, such as tinfoil, to about two-thirds of its height, both on the inside and the outside. A brass rod extends through an insulated stopper; the lower end of the rod is connected with the inside coating by means of a brass chain and terminates in a knob on its upper end. Modern electrical apparatus is usually equipped

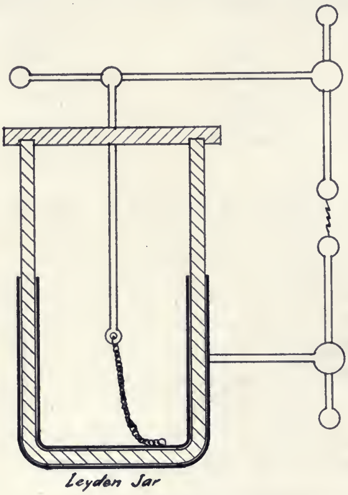

Fig. 6

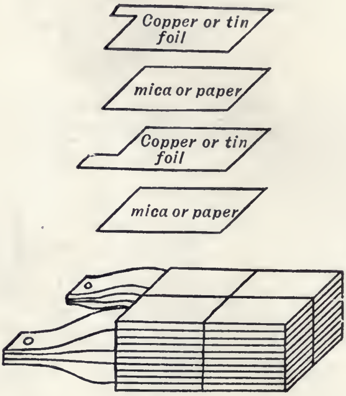

Fig. 7

Fig. 6.—Diagram of Leyden jar, its discharge through a "spark gap."
Fig. 7.—Plate condenser.

with plate condensers, consisting of a number of flat metal (copper) sheets separated by insulating material (mica). The alternate layers of the conducting material are connected to the terminals of an electrical source. A large capacity can be built up in these plate condensers.

Fig. 8.—Electric repulsion. A person seated on an insulated platform receives a charge from a static machine; the charge spreading all over the body electrifies each hair similarly and as a result each hair repels its neighbor.

Static Electricity.—Static or frictional electricity is the first known form of electricity. The Greeks observed that amber—the Greek name of which is elektron—when rubbed, would attract light objects, such as feathers, or bits of paper. Gilbert, physician to Queen Elizabeth, discovered that glass, sulphur, resin and some other substances possessed the same property as amber and he coined the name electricity (electricitas) from the Greek word.

When dissimilar substances, preferably non-conductors of electricity, are rubbed some substances take on an excess of electrons, while others are left with a deficit of electrons. Those with an excess of electrons are considered to possess a negative charge, while the ones deprived of their electrons are considered to be charged positively.

Electricity produced by friction is held on an insulated conductor in a state of tension, ready to flow away, and is called "static" electricity, in contrast to "current" electricity which flows all the time.

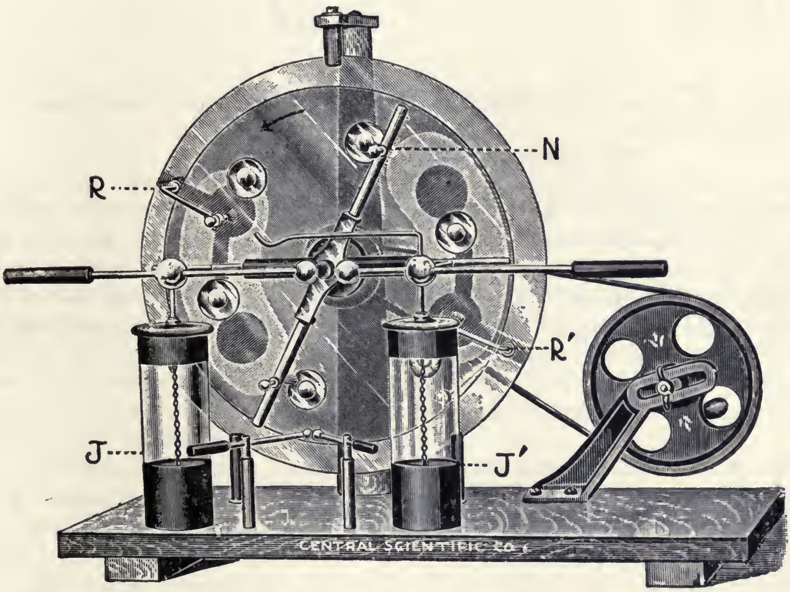

Fig. 9.—Primitive static machine (Tœpler-Holtz type). *R–R′*, contact brushes; *N*, diagonal bar for neutralizing charges; *J–J′*, small Leyden jars to increase capacity of apparatus.

Lightning may be explained by the separation of electric charges on the heavy raindrops from the thunderclouds by the violent air currents. The negative charges remain on the finest particles blown high into the air while the heavy positively charged raindrops are left behind. Thus an electric field of enormous tension is created and, due to the overpowering pull of the lines of force, the charges rush forward, ionize the air (making it a conductor) and there is a lightning flash.

The *static machine* is a miniature generator of lightning. In its primitive form it consists of two circular glass discs mounted on a spindle, with only a small space between them. When rotated by a handle, or by motor power, at high speed, a separation of electric charges takes place and metallic brushes draw off the positive and negative charges from the revolving disc, leading them to two metallic "prime" conductors or terminals. When the difference of potential between these two terminal conductors becomes sufficiently high an electric discharge occurs in the form of a spark.

CURRENT ELECTRICITY

Electric Current.—A stream of loose electrons passing along a conductor is called a current of electricity. To establish or maintain an electric current it is necessary that there be a source of energy generating an

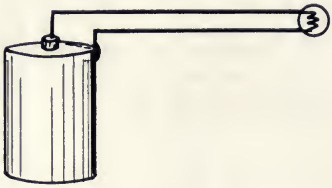

Fig. 10

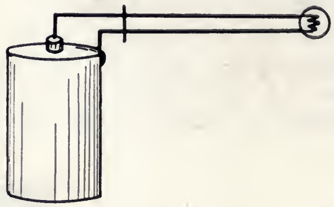

Fig. 11

Fig. 10.—Electric circuit.
Fig. 11.—Short circuit. An accidental overflow of current due to an establishment of a low-resistance by-pass.

electric charge and there be a complete electrical circuit maintained between the higher and lower level of electrons. The path of the current from the generating source through the various conductors back to the generating source is called an *electric circuit.* As the electric current flows, the circuit is said to be "closed;" if an interruption or a break occurs the circuit is said to be "open" and the current ceases to flow. This terminology

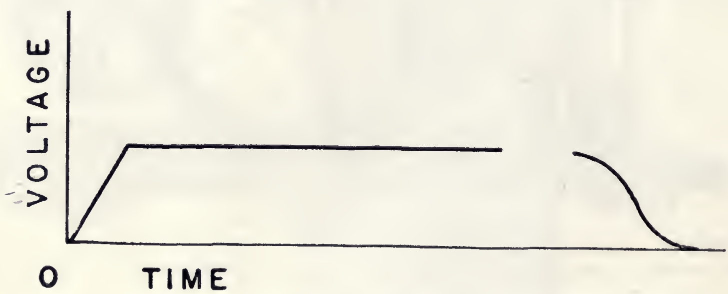

Fig. 12.—Diagram of direct current derived from an electric cell.

originates from the employment of switches, which are closed in order to start the current and opened so as to discontinue it; although expressing just this action, it nevertheless is a source of confusion for the beginner in electrotherapy.

Two forms of current are employed in every-day commercial life, the direct and the alternating. In the case of direct current (D.C.) the flow of electrons continues unchanged in the same direction, while in the case of alternating current (A.C.) the direction of flow changes periodically, as shown diagrammatically.

The voltage of the alternating current is represented by a double curve, one-half above and one-half below the neutral level. Each part of the curve is called an impulse or alternation; two successive alternations constituting a cycle. The time consumed in the completion of a cycle is called a period. The number of cycles occurring in a second is called the frequency of the current. The ordinary alternating current usually alternates at a rate of 60 per second and is therefore a current of 60 cycles and 120 alternations. In every-day usage we designate as low-frequency currents those of a frequency of less than 10,000 a second, while the term high-frequency current designates a current with 100,000 or more cycles per second.

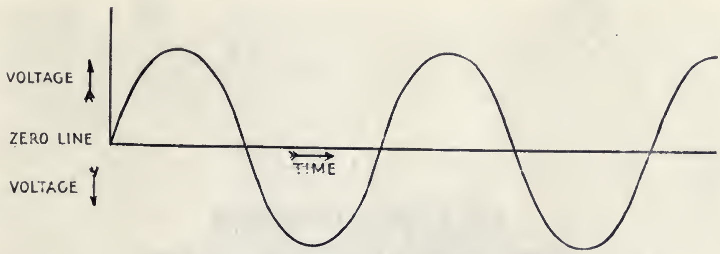

FIG. 13.—Diagram of alternating current.

EFFECTS OF CURRENT ELECTRICITY

The existence of an electric current is made evident by the following effects: (1) Heat is developed in all parts of the circuit. (2) Every part of the circuit deflects a magnetic needle brought near it. (3) Chemical action takes place under certain conditions. All forms of currents produce thermal and electromagnetic effects. Chemical action is mainly produced by the direct current; the changes in direction of flow in the alternating current interfere with the regular movement of ions upon which chemical action is based. Currents of very rapid alternation (high-frequency currents) exert no chemical action at all.

1. **Thermal Effects.**—All electrical currents cause a rise of temperature in a conductor, due to conversion of electricity into heat. The facts regarding this effect were established by Joule in 1877 and are known as *Joule's laws:*

1. The heat produced is directly proportional to the square of the current strength.

2. The heat produced in different conductors is directly proportional to the resistance of each conductor.

3. The resulting quantity of heat is in direct proportion to the duration of the passage of the current.

Both direct or alternating currents produce heating effects in solid conductors. Heating occurs also when a direct current passes through an electrolytic solution, but this is due to chemical changes, and is, therefore, only a secondary effect.

Joule's laws are of great importance in considering the heating action of alternating currents of rapid oscillations (high-frequency currents) on the body. The tissues of the body possess a varying resistance and those of higher resistance should heat up more when traversed by the electrical current. The electrical current, however, will not pass along a high resistance if there is a parallel path of lower resistance available.

The heating effects of electric currents find extended use in every-day industrial life wherever the changing of electric energy into heat or light is desirable. The light of incandescent lamps is produced by the passage of a current through a filament of high resistance, such as carbon or tungsten. Arc lights consist of two carbons placed at a short distance from each other; a powerful current jumps an arc between the two and produces a brilliant light. In electric radiators and heaters the resistance of the wire produces the desired heat. In the electric cautery a loop of platinum wire becomes heated.

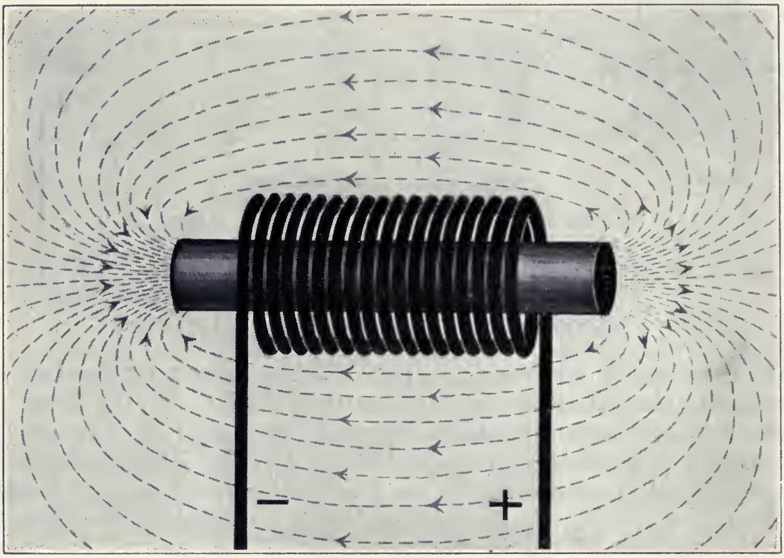

Fig. 14.—Electromagnetic field.

The heating effect of electricity on a conductor is directly proportionate to the intensity of current and inversely proportionate to the cross-section of the conductor; hence the necessity of proper size wiring in every circuit to prevent overheating of the wires with the consequent danger of fire. The protecting action of an electric fuse is based upon the fact that a current of excess strength develops enough heat in a calibrated length of lead alloy to bring it to immediate melting, thus the flow of the current is interrupted and overheating of other parts of the circuit is prevented.

2. **Electromagnetic Effects.**—A magnet is a substance which has the power to attract, according to its size, small or large particles of iron or steel. It also has the property of setting itself in definite relation to the earth, when freely suspended. These effects are produced by what is called a magnetic field surrounding a magnet. An electric current also sets up a magnetic field. An electromagnet consists of a length of insulated wire (electric coil) wound around a soft iron core. When an electric current is passed along the wire, the core temporarily acquires the properties of a magnet.

The electron theory explains electromagnetic phenomena by picturing magnetism itself as due to the movement of electrons within the atom. If a wire carrying a direct current is brought over a magnetic needle and parallel to it, it will deflect the needle at right angles. The magnetic needle can be taken as representing a molecule of an iron core in an electromagnet, and each molecule of iron has an electromagnetic effect. The flow of electrons in the neighborhood of the wire makes these infinitesimally small

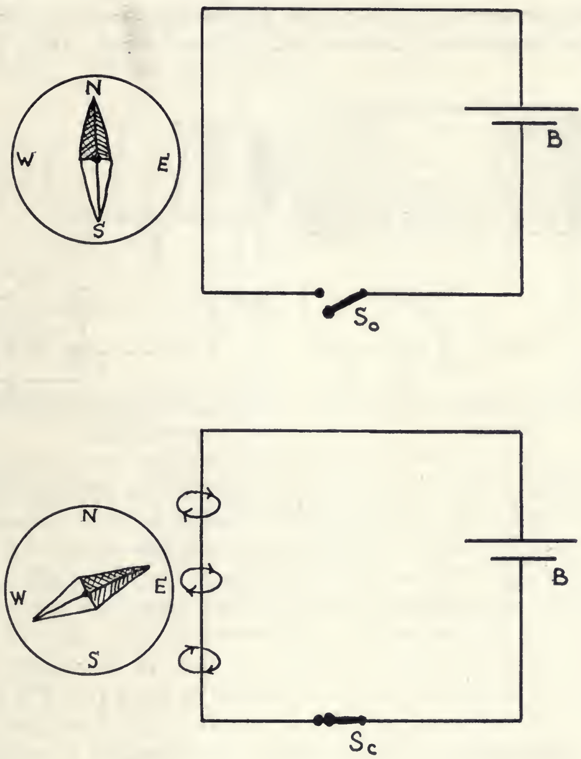

FIG. 15.—Deflection of magnetic needle by an electric current. *B*, battery; *So*, switch open (no current); *Sc*, switch closed (current flowing).

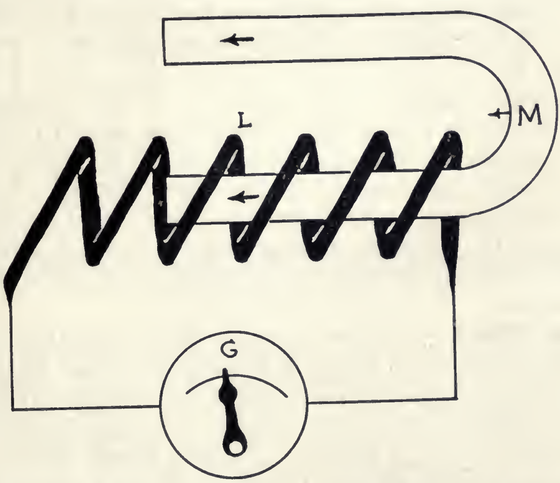

FIG. 16.—Production of current by movement of magnet surrounded by a coil. *L*, coil; *M*, magnet; *G*, galvanometer. Arrow indicates motion of magnet.

magnets take up definite position, just as the magnetic needle does, and produce the phenomena of magnetism. As long as the electrons are kept moving along the wire the magnetic effect continues. On the principle of electromagnetic influence is based the *galvanometer*, the sensitive instrument for the measurement of the direct current, the amount of the deflection of the needle varying with the strength of the current. (Fig. 15.)

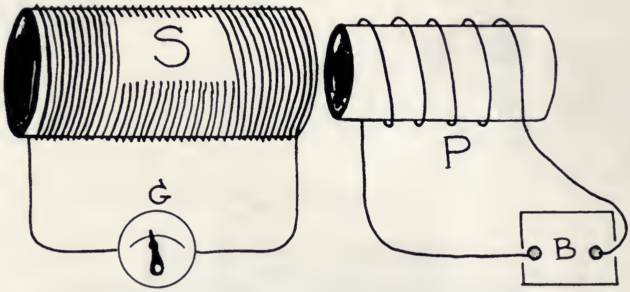

FIG. 17.—Production of current in a coil by a current flow in a nearby coil. *P*, primary coil; *B*, battery; *S*, secondary coil; *G*, galvanometer.

Corresponding to the force effected by a current upon a magnet, there is a reciprocal action of a magnetic field upon a current. If a coil carrying a current is hung in a magnetic field so as to be free to move it will tend to turn so that its plane will be at right angles to the line of force of the field. This principle finds an important application in the electric motor.

Electromagnetic induction was discovered by Faraday in 1831, who observed that it is possible to "induce" a flow of electricity in a coil of insulated wire, if a magnet is moved toward or from this coil or if the coil is moved to or from the magnet. The two most important laws of Faraday are: (1) An alternating electric current is generated ("induced") in an electric circuit, whenever in a nearby circuit an electric current of varying strength (an interrupted direct current or an alternating current) flows. (2) An alternating electric current can also be induced in an electric circuit if a magnet is moved near to it or if the circuit is moved in relation to the magnet. (Fig. 16.)

Electromagnetic induction also enables us to turn mechanical power directly into electrical power and, through the means of the dynamo, serves as the basis for the large-scale production of electricity. In the most important devices in the modern uses of electricity, such as the faradic coil, the induction coil, the electric motor, the electric bell, the telegraph, the telephone and the radio, as well as in most electrotherapeutic apparatus, the principle of current production is inevitably linked up with electromagnetic induction.

3. **Chemical Effects.**—Solutions of acids, bases or salts, known as electrolytes, dissociate into free atoms or groups of atoms. These free atoms all bear an electrical charge; bases, metals and alkaloids are electropositive, acids and acid radicals being electronegative. These electrified particles have been named ions, or wanderers. When a direct electrical current is applied to an electrolytic solution the ions begin to wander; those with a positive charge are attracted toward the negative pole, or cathode, and

those with a negative charge toward the anode, or positive pole. The process of dissociation is known as *ionization*.

The electrical decomposition of an electrolyte is a complicated process. It consists essentially of two phases and is shown in the example of the decomposition of a solution of common salt. (1) Primary reaction; redistribution of ions. (2) Secondary reaction; forming of new chemical bodies at the electrodes. (Figs. 18 and 19.)

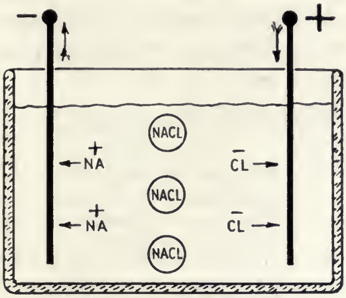

FIG. 18

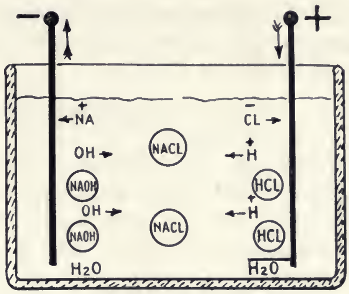

FIG. 19

FIG. 18.—Primary chemical reaction in salt solution under the influence of an electrical current. Redistribution of ions in the solution. Sodium ions migrate to cathode, chlorine ions to anode, undivided sodium chloride molecules move in no definite direction.

FIG. 19.—Secondary chemical reaction in salt solution. Formation of new chemical bodies at the electrodes. Sodium ions become neutralized at the cathode, caustic soda and free hydrogen are formed ($2Na + 2H_2O = 2NaOH + H_2$). Chlorine ions become neutralized at the anode hydrochloric acid and free oxygen are formed ($2Cl + H_2O = 2HCl + O$). At the negative pole, as a rule, bodies of alkaline reaction are formed (litmus turns blue), and at the positive pole bodies of acid reaction are formed (litmus turns red).

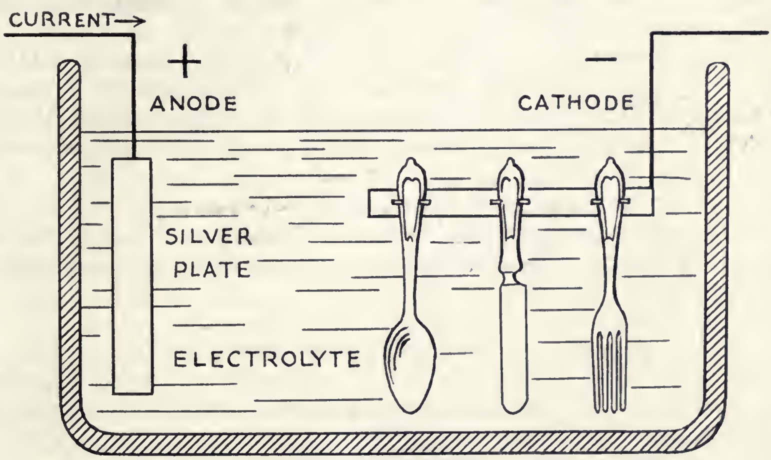

FIG. 20.—Diagram of silverplating.

The chemical effects of the direct or galvanic current are extensively used in industry for electroplating, electrotyping and, also, for production of chemicals on a large scale. In silver plating, for instance, the article to be plated is immersed in a solution of some silver salt and attached to the negative pole while a rod of silver is used at the positive pole. When the current flows a thin coating of silver is evenly deposited all over the surface of the object connected to the cathode. (Fig. 20.)

ELECTRICAL UNITS

The analogy of water flow has been employed for a long time to visualize the conditions of the flow of electrons through a conductor. Water would remain stationary in a pipe unless pressure is present to cause it to move. Such pressure is furnished either by a pump or by a difference in level between a high tank and the ground. Similarly, a difference of potential sets up the flow of electrons, and is brought about by a generator of electricity. The pressure or tension of the electrical current is in direct proportion to the difference of potential and is known as the electromotive force (E.M.F.) or voltage.

TABLE 4.—COMPARISON OF WATER SYSTEM AND ELECTRICITY

Water system	Electricity
Pressure or head	Voltage or potential
Rate of flow or volume per unit second	Amperage
Pump	Dynamo or generator
Pipes	Wires or conductors
Water circuit	Electric circuit
Valves	Switches
Valve open (water flows)	Switch closed (current on)
Valve closed (no flow)	Switch open (no current)
Pipes leaking	Short circuit
Pipes stopped up	Open circuit (no current)
Pressure gauge	Volt meter
Water meter	Ammeter
Water power	Wattage

1. **Unit of Current. The Ampere.**—The rate of a current of water flowing through a pipe may be expressed as a certain number of gallons per second. Similarly the rate of a current of electricity may be expressed as a certain quantity of electricity flowing per second past a certain point. By international agreement, the quantity of electricity which deposits 0.001118 gram of silver is *one coulomb* and the current which deposits silver at a rate of 0.001118 gram per second is *one ampere*. The ampere is the unit quantity of electricity flowing per second and serves as the unit of measuring the flow of electricity.

For commercial purposes (lighting, starting motors, etc.) a current flow of several hundred amperes may be used. For electromedical work much less rate of flow is required; therefore, as a measuring unit, only $\frac{1}{1000}$ ampere called the *milliampere* is employed.

1 MA. = 0.001 ampere.

Of the various therapeutic currents, the static current employs the smallest rate of flow of electricity, 0.1 to 1 milliampere; the faradic current amounts to little over 1 milliampere; the galvanic current varies from 1 to 20 milliamperes; the largest rate of flow is used in high-frequency treatments, from 500 to 1500 or, frequently, even more milliamperes.

2. **Unit of Resistance. The Ohm.**—A stream of water flowing through a pipe is retarded by the friction of the pipe. A longer and smaller pipe offers more resistance than a large and short one. The opposition offered by the electrical conductors to the flow of current is known as the electrical resistance and its factors are the material, the length and the diameter of the conductors.

The unit of electrical resistance is the *ohm* and by international agreement 1 ohm represents the resistance of a column of pure mercury, 106 cm.

high and 1 sq. mm. in cross-section, at a temperature of 0° C., that of melting ice.

3. **Unit of Electromotive Force. The Volt.**—In order to get water to flow along a pipe it is necessary to have some driving force due to a pump or to a difference in water level. In order to get electricity to flow along a wire we must have an electromotive force. This may be furnished by the difference of potential of an electric cell or battery or by some other electric generator.

The *unit* of electromotive force or pressure is known as the *volt.* It represents the electromotive force or "push" needed to drive a current of 1 ampere through a resistance of 1 ohm.

The voltage in the commercial current for lighting and power is either 110 or 220. High power transmission lines carry a voltage from 2000 to 20,000. The voltage in storm clouds amounts to several millions, bringing about the tremendous electrical discharges of lightning. For a spark discharge across the very high resistance of separated electrical terminals ("spark gaps") the necessary amount of electromotive force varies with the distance of the terminals. It is estimated that a 1-inch spark requires about 10,000 volts; a 4-inch spark, about 52,000 "effective" volts.

For electromedical currents the voltage of the supply circuit is considerably modified; it may be decreased by an interposed resistance or increased by "step-up" transformers. Galvanic, faradic, and sinusoidal currents employ up to about 75 volts and are consequently grouped as low volt or low-tension currents. High-frequency and static currents employ from several hundred to several thousand volts and are grouped as high volt or high-tension currents.

Difference Between Amperes and Volts.—The beginner in electricity is usually confused as to the distinction between volts and amperes; comparison with water, as shown in Table 4 will help to clear up some of the difficulty. With both water and electricity there must be a motive force (head of water or difference of potential) in order to get a flow of current, but we may have the motive force and yet have no current. A closing of a valve in the water pipe acts like an open switch in electricity. There is a motive force or pressure (volts) but no current (amperes). The greater the electromotive force in a given circuit, the greater is the flow of current per unit time; the greater the pumping force or head in case of water, the larger the number of gallons flowing through a given pipe. In other words: electrical current denotes the rate of flow, electrical resistance the opposition which regulates the flow and voltage the moving force which causes the flow.

Ohm's Law.—All calculations of electrical measurements are done with the aid of *Ohm's law* which states: *In an electrical circuit the flow of current (amperage) is in direct proportion to the electromotive force* (voltage) *of the generator and inversely proportional to the resistance of the circuit.*

Ohm's law can be easily explained with the simile of water. When water is forced through a pipe by a pump, the stream which results is in direct proportion to the pressure exerted by the pump and in inverse proportion to the resistance of the pipe. Similarly in an electrical circuit the current is in direct proportion to the electromotive force or voltage of the generator or electrical cell and inversely proportional to the resistance of the circuit.

On account of the definite relation of these three factors, any two given furnish a description of the circuit, for the third can easily be calculated. For instance, the voltage of a simple galvanic cell is about 1.5, and if applied against a body resistance of about 1000 ohms it will produce, according to Ohm's law, 1.5 ÷ 1000 = 0.0015 ampere, or 1.5 milliamperes, of current. So, too, if we know that the voltage of a given current is 50 and the milliampere reading when applying it to the body is 10 milliamperes, we learn that the resistance of that part of the body is 5000 ohms.

Ohm's law is of prime importance in every application of electrical current in medicine. Its consideration teaches that there are two ways of increasing the current in a given circuit, either by increasing the voltage or by decreasing the resistance of the circuit through which the current passes. Increasing the size of electrodes, decreasing their distance from each other and decreasing the resistance of the skin by moistening, all tend to decrease the ohmic resistance and thus increases the flow of current through the body.

4. **Unit of Power. The Watt.**—The work or energy of a flow of water is measured by the number of gallons flowing, multiplied by the pressure in the pipe in a unit of time; similarly electrical power is equal to the product of the current flowing and the electromotive force (voltage) impressed for a given period of time. A statement that 10 amperes are passing in a circuit or that 100 volts are applied is no complete description of the electrical energy employed. It is necessary to state how many amperes at a certain voltage are passing in a given circuit. The total amount of electrical energy is the product of volt × ampere, which is expressed in watts.

The *watt* is the unit of electrical power and 1 watt represents the power delivered when the current flows at the rate of 1 ampere with a pressure of 1 volt. The watt is thus nothing more than the measurement of the rate at which power is consumed.

The unit of quantity used in figuring the cost of power either produced or consumed is the *kilowatt.* Ten amperes flowing in a circuit where the pressure is 100 volts means by power is being delivered at the rate of 1000 watts (10 × 100). One thousand watts are equal to 1 kilowatt, or 1 kw. When power is delivered at the rate of 1 kilowatt for one hour the quantity of power is called 1 kilowatt hour, or 1 kw.h. Electric power companies charge a varying amount per kw.h., ranging, for instance, from 7 cents in residential districts to 4½ cents to large commercial consumers.

Those installing and employing electrotherapeutic equipment may easily figure out its running cost, as each lamp and each piece of apparatus usually bears a label giving the wattage consumed. For instance, if one operates an electric motor that consumes 250 watts it will consume 1 kilowatt hour in four hours, or ¼ kilowatt hour in one hour. If the rate is 7 cents per kilowatt hour it will cost ¼ of 7 cents or less than 2 cents to run the motor for one hour.

What is the cost of burning a 150-watt lamp for two hours continuously if current costs 7 cents per kilowatt hour? 150 watts multiplied by 2 amounts to 300 watt hours or less than ⅓ kilowatt hour. Thus the cost would be a little over 2 cents for two hours, or about 1 cent per hour. These calculations show that, after all, the cost of electric power is almost the smallest of the expense items involved in electrotherapy.

5. **Unit of Capacity. The Farad.**—One farad represents the capacity of a condenser which charged with 1 coulomb gives a difference of potential

of 1 volt. This unit is so large that one-millionth of it is taken as the practical unit, and is called the *microfarad.* The capacity of condensers is usually expressed in microfarads.

MEASURING AND REGULATING DEVICES

Measuring instruments of the amperage and voltage of the direct and alternating current are based on the electromagnetic effects of the current. A meter consists of a box having a magnetic device that actuates a pointer in proportion to the current passing through the meter.

Ampere Meters and Voltmeters.—An *ammeter* (contracted form of ampere meter) measures the rate of flow of the electric current. Most of the electromedical meters read in milliamperes, expressing 1:1000 part of an ampere. Such a meter is called a milliampere meter or, in abbreviated form, a *milliammeter.*

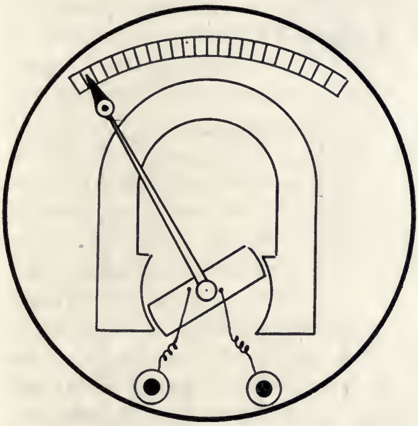

Fig. 21.—Ampere meter for direct current.

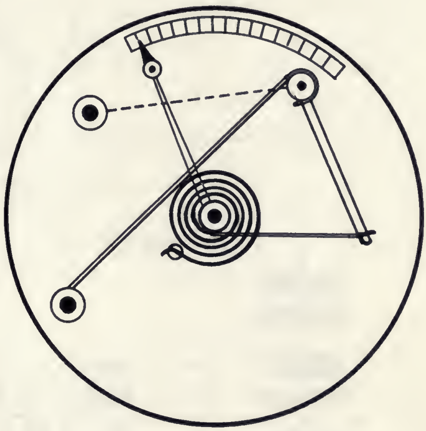

Fig. 22.—Hot-wire meter for high-frequency current.

Meters for direct current are constructed on the principle of the galvanometer; the electromagnetic deflection of a pointer connected to an electric coil. A permanent magnet maintains a uniform magnetic field through which the current to be measured flows. A rotating force is imparted upon the coil in proportion to the current strength. The pointer of the meter connected to this coil is deflected accordingly. (Fig. 21.)

Meters for alternating current utilize the principle of magnetic repulsion between two soft iron vanes situated in the same magnetic field. A newer form of alternating current meter employs a small rectifier to change the alternating current to direct, the meter itself being of the direct current type.

Meters for high-frequency current are designed on two different principles: (*a*) Hot-wire type—in which the heating effect of a current causes an expansion of the wire in proportion to the current strength. The wire being attached to a rotating drum, the movement of the wire causes a deflection of the pointer. (Fig. 22.)

(*b*) Thermocouple type, based on the principle of the thermocouple. A thermocouple consists of the junction or joint of two dissimilar metals.

When such a joint is heated, a difference of potential (voltage) is developed which is proportional to the temperature of the junction. The current that flows in a circuit due to the voltage so developed is always a direct current regardless of the nature of the heating agent. Hence, a high-frequency current forced through a thermocouple will generate heat in the junction, which in turn develops a direct current in proportion to the heat generated by the high-frequency current. Connecting the wires from each side of the thermocouple to the moving coil of a very sensitive direct current meter, which has been properly calibrated, readings are obtained in high-frequency milliamperes. Such a meter referred to either as a high-frequency or a radio-frequency meter of the thermocouple type is now used in most of the high-frequency apparatus.

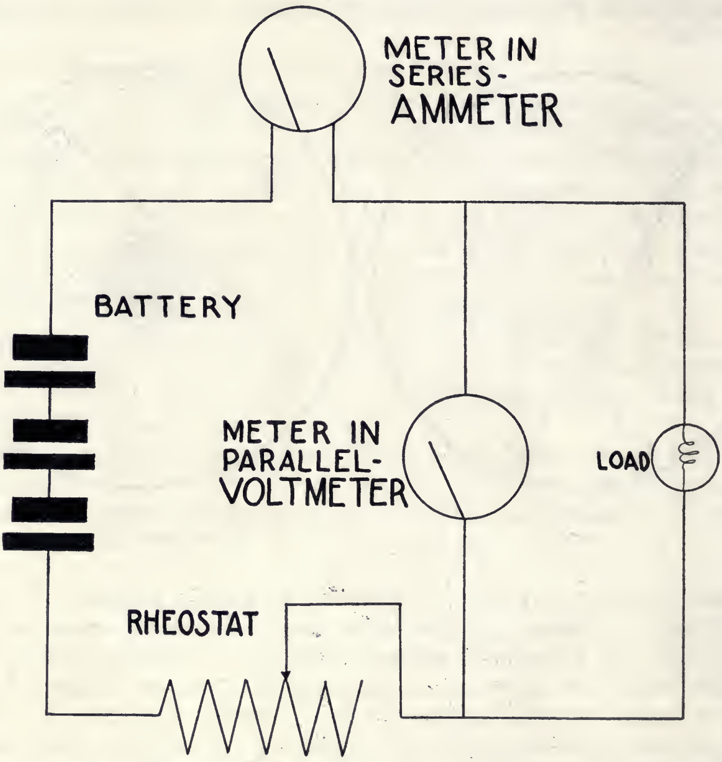

FIG. 23.—Schematic diagram showing method of connecting ammeter and voltmeter in any circuit. The ammeter, A, is connected "in series" so that the current passes through it, while the voltmeter, V, is connected across the line—in shunt—so that the full voltage is impressed upon it, yet by-passing the current.

A *voltmeter* serves for the exact measuring of the voltage of the electric current. Such measurement is important for more accurate work, as for instance in electrodiagnostic procedures (condenser testing). A voltmeter is a sensitive ammeter which has a high resistance of some thousands of ohms placed in series with it so that the current that flows through the meter is extremely small and is a function of the voltage. Thus, with a scale calibrated in volts it gives a reading directly in volts. (Fig. 23.)

All meters require accurate calibration from the start and must be treated with the greatest of care. The pointer in the better quality of meter revolves in a carefully constructed socket, consisting of some hard semiprecious jewel, usually a ruby, and which is very sensitive to jolts and vibrations. A meter must likewise be very carefully guarded against sudden strains by too strong a current. Most meters are provided with a set-screw for accurate adjustment. With no current flowing through the circuit, the pointer should be checked and carefully adjusted to zero.

For measuring small and large currents applied from the same low-voltage apparatus two-scale *meters* are used, which are so constructed that on proper setting of a control small currents pass directly through the coil of the meter, while heavier currents pass only partly through. In long-wave diathermy apparatus often two meters are provided, one for low and the other for high reading.

Measuring Power in Alternating Current Circuits.—In alternating current circuits, due to the continual variations in intensity and periodic changes in direction of flow of an alternating current, as illustrated in Figure 13, a *reactance* is encountered in the circuit which causes a "phase displacement" between the current and the voltage. This means that the current and the voltage are actually out of step with each other, with the current either leading or lagging behind the voltage. The reactance and ordinary ohmic resistance of the circuit combine geometrically to produce a new kind of resistance to the flow of current, known as *impedance*. In order to measure power in an alternating current circuit, a wattmeter must be used, therefore, for measuring the voltage and amperage. A voltmeter and ammeter would give an apparent wattage which is higher than the true power being consumed.

In average electromedical equipment, such as diathermy and short-wave apparatus, the actual power being consumed and paid for will vary from 50 to 80 per cent of the apparent power. Where electric sterilizers, ordinary incandescent lamps for lighting purposes, radiant light and heat lamps, and bakers are used, the apparent watts will be equal to the true watts as would be the case if direct current was being used. The reason for this is that these last-named devices do not have an appreciable property of inductance and hence do not introduce reactance in the circuit which would cause the current to be displaced.

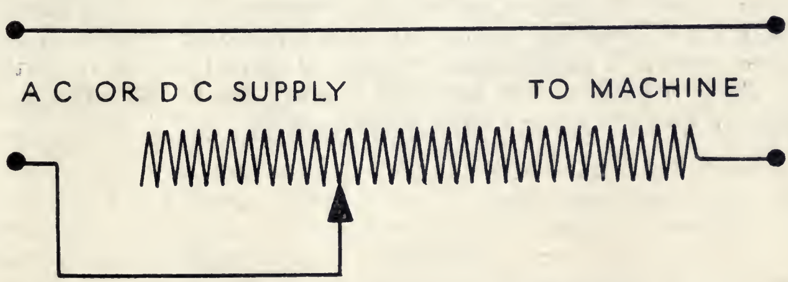

FIG. 24.—Diagram of a rheostat with sliding contact.

Rheostats.—A rheostat or resistance unit makes use of the resistance of certain conductors or combinations of alloys, placed in the path of the incoming current to the apparatus to regulate the amperage. There is usually a very negligible flow of current when the full resistance is in the circuit, and as the control is gradually advanced, the resistance is decreased and the current flow is correspondingly increased.

A rheostat of the type most generally used in electromedical apparatus consists of a single layer of resistance wire wound on a straight or a circular form and so arranged that a sliding contact cuts in or out as much of the coil as is necessary to give the required current. (Fig. 24.)

For the regulation of alternating currents supplying electromedical apparatus, a current controlling device known as a *choke coil* is used. A choke coil consists of several layers of insulated copper wire wound on an open or closed iron core. Taps brought out from given points of the coil to contact buttons, with each of which a moving contact arm makes connections and permits of the control of current. If a coil of wire forms part of an electrical circuit through which an alternating current is flowing each alternation induces within the coil a momentary counter electromotive force caused by self-induction. This self-induction is thus used to control the flow of alternating current in a circuit. (Fig. 25.)

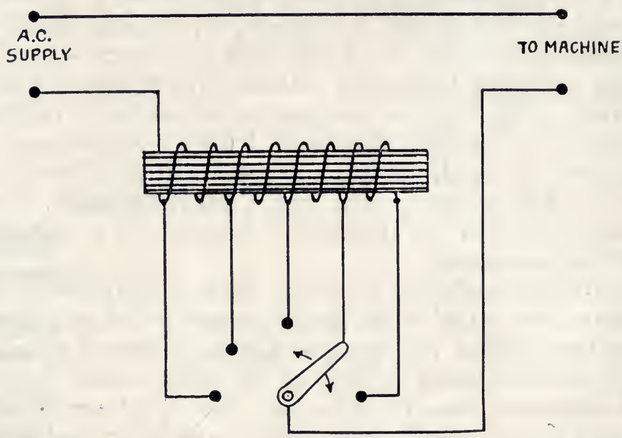

Fig. 25.—Diagram of choke coil.

A rheostat will regulate the current in both direct and alternating current circuits in the same manner and practically to the same degree since with both types of circuit ohmic resistance functions in the same manner. A choke coil will function as such only with alternating current. If used on direct current it would impede the flow of current only to the extent of its ohmic resistance. The impeding property due to self-induction or inductance would be *nil* in a direct current circuit.

CHAPTER III

GENERATION, CONVERSION AND DISTRIBUTION OF ELECTRICITY

Chemical Generation. Cells and Batteries. Mechanical Generation. The Dynamo, the Electric Motor, the Faradic Coil, the Transformer, the Rotary Converter. Electric Oscillations and Waves. Electronics. Thermionic Emission. Vacuum Electronic Devices. Gas-filled Electronic Devices. Electrical Current Supply in Homes and Offices. Measuring and Protecting the House Supply. The Rôle of Fuses. Locating Trouble. Current Outlets.

LIKE any other form of energy, electricity can neither be created nor destroyed, but it can be made manifest by the transformation from another kind of energy. Thermal, chemical or mechanical energy can be converted into electrical energy, and this new form of energy can again be readily transformed into heat, light, and other useful forms of energy.

The thermoelectric method of producing electricity is based on the principle of the thermocouple (Chapter II). A series of thermocouples is known as a thermopile or thermoelectric battery, but such a device is only employed for laboratory work. For the production of electricity on an extended scale, only the chemical and mechanical means of generation are suitable and will be here considered.

CHEMICAL GENERATION OF ELECTRICITY

Cells and Batteries.—The chemical production of electricity is caused by the liberation of electrons when metals go into chemical solution. In a solid metal the atoms are in neutral condition.

When plates of two dissimilar metals, such as copper and zinc, are placed in a vessel containing an electrolyte, as, for instance, dilute sulphuric acid, chemical action takes place, particles of zinc enter the solution as positive ions, repelling the positively charged hydrogen ions toward the copper plate on which they appear as free hydrogen. The copper plate thus becomes positively charged and the zinc plate, negatively—due to the negative charge remaining after removal of the positive zinc ions. Connecting the two metals by a wire or conductor a stream of electrons of a galvanic (direct) current will flow from the copper to the zinc plate.

Each of the known metals, when employed in a galvanic cell produces an electric potential which is characteristic of that metal. In the *electromotive series* of metals any metal is electropositive to any other following it. The series is as follows: silver, mercury, copper, lead, tin, nickel, iron, zinc, aluminum, carbon. The further apart the metals in the series, the greater potential difference can be obtained.

A *galvanic cell* consists of two metals and an electrolyte. The positive terminal or anode is the binding post at which the current leaves the anode; the negative terminal is the binding post at which the current returns to the cathode. In the copper-zinc cell the copper plate is the positive and zinc plate is the negative electrode; in the zinc-carbon cell the zinc plate is the negative and the carbon the positive electrode. Within the cell the electrons will flow in the opposite direction to the current flow in the outside circuit, but the current flow within the cell is in the same direction. (Fig. 26.) The signs positive or anode (+) and negative or cathode (−), on instrument boards, plugs and sockets have no other meaning than that of designating the direction of the flow of electrons. Electrons always flow from the higher level to the lower level, *i. e.*, from the anode to the cathode; the current itself flows from the cathode to the anode.

Wet cells are no longer used because of the secondary changes in the substance of the electrolytes and in the electrodes, with a resulting electromotive force opposite to the direction of the original current, known as *polarization*.

Dry cells (Fig. 27) consist essentially of a zinc container lined with thin blotting-paper, which serves as the negative electrode, and a carbon rod in the center as the positive electrode; a hygroscopic

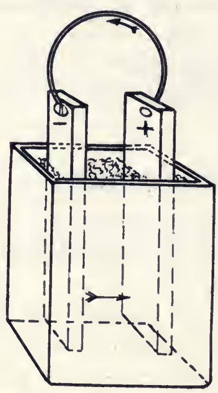

Fig. 26.—Direction of current flow in an electric or galvanic cell.

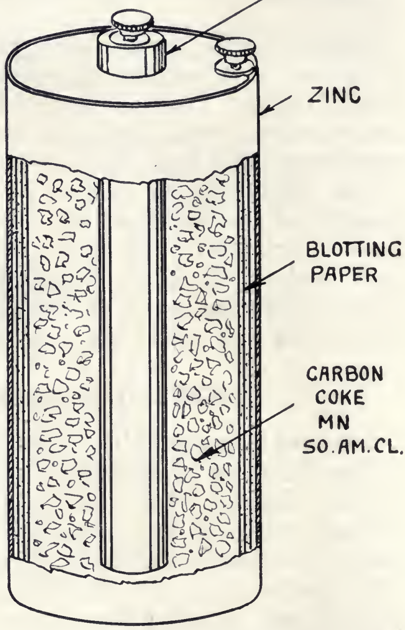

Fig. 27.—Dry cell.

mass, consisting of ammonium chloride, zinc chloride, manganese dioxide and granulated carbon, combined with water in the form of paste, fills the space between the electrodes and so prevents polarization. The top of the cells is made water-tight by a layer of pitch. Dry cells are clean, are easily portable, and have proved useful for modern commercial purposes, where an even flow of a small amount of current is needed, as for the ringing of door bells, for pocket flashlights, etc. The voltage of an ordinary dry cell is about 1.5 volts, and the average resistance encountered in the body is about 1000 ohms; hence one cell will produce in the body about 0.0015 amperes, or 1.5 milliamperes of current.

An electric *battery* consists of a number of cells joined together in series. The development of the radio industry has brought about the construction of dry batteries of large capacity, 45 or more volts, which are now widely employed in portable galvanic apparatus.

Storage batteries are "reversible" batteries which can be loaded with electrical energy from the line current and almost all of this energy put into them can be taken out again; this process can be repeated for a year or so without renewing the battery. The metal used in storage batteries is lead and the electrolyte is sulphuric acid.

MECHANICAL GENERATION AND CONVERSION OF ELECTRICITY

Dry cells and batteries are somewhat expensive sources for producing large quantities of electricity. Faraday's epoch-making discovery of electromagnetic induction laid the groundwork for the modern age of electricity by making possible the convenient, cheap and wholesale transformation of mechanical energy into electrical energy. Electricity is generated at central stations and from there is distributed through suitably insulated electric wires to homes, offices and factories.

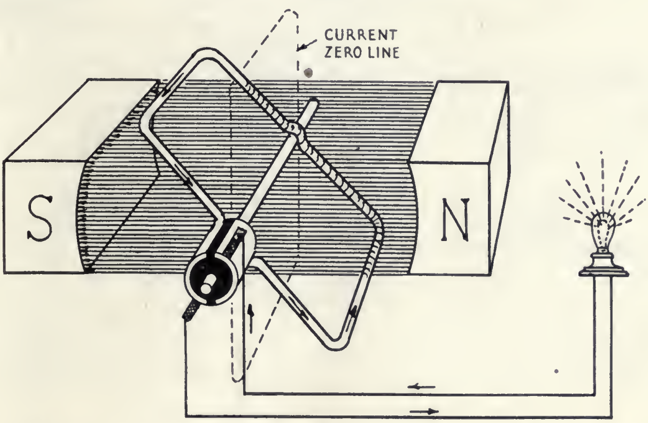

FIG. 28.—Diagram of dynamo. In any closed circuit which is penetrated by lines of force of varying intensity, an electric current is induced. This diagram represents a wire loop, rotating in a magnetic field. With every half revolution the amount of lines of force by which it is penetrated changes from zero to maximum and back to zero; the intensity of the current generated within the loop and the light from the electric bulb connected to it vary correspondingly.

The Dynamo.—The dynamo (Fig. 28) is an apparatus for the conversion of mechanical energy into electrical power. Its chief parts are: (1) The magnetic field, produced by electromagnets or powerful permanent magnets; (2) the armature, a coil of insulated wire mounted around a specially designed iron core; (3) the collecting mechanism which consists of metallic brushes (to make a sliding contact), slip rings (copper rings which rotate with the armature) in alternating current dynamos or a commutator (a split-ring device to collect a direct current) in direct current dynamos; and (4) an activating mechanical power, steam, gasoline or water power which keeps either the armature or the electromagnet moving in relation to each other. The mechanical power expended in rotating the armature is transformed into electrical energy, because the rotation sets up a magnetic force which opposes this rotation and the energy spent to overcome this force becomes the electrical energy.

The Electric Motor.—The electric motor is the reverse of the dynamo, for it is an apparatus for the conversion of electric energy into mechanical one. It consists of an armature rotating in a magnetic field. The electromagnetic force will tend to rotate the armature, and the shaft of the armature transfers the mechanical power created by this rotation by gearing or belt to other apparatus. Motors are built for operation on either alternating or direct current, and certain small motors may be used on both alternating and direct current.

The Faradic Coil.—This is a device for the production of an induced (faradic) current from a direct current source. Its essential parts are: (1) A primary coil, consisting of a few turns of insulated thick wire wound around a soft iron core, the latter strengthening the magnetic field around

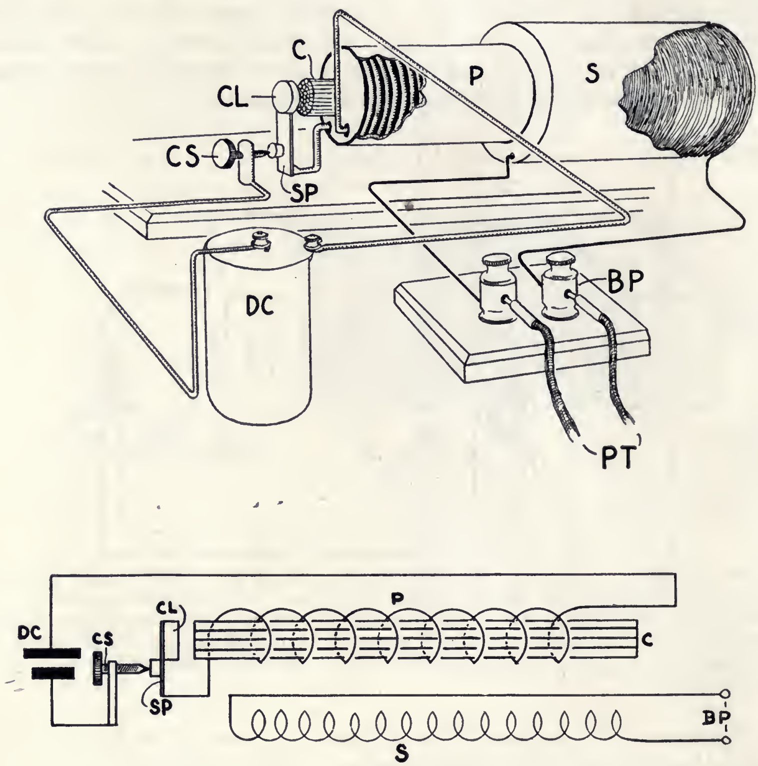

FIG. 29.—Schematic diagram of faradic coil. *P*, primary composed of turns of heavy wire; *S*, secondary composed of many turns of fine wire; *C*, soft iron core; *CL*, soft iron clapper; *SP*, spring; *CS*, contact screw; *DC*, dry cell; *BP*, binding posts; *PT*, leads to patient.

the primary coil; (2) a secondary coil, consisting of many turns of insulated fine wire; (3) an interrupting device (vibrating armature), which makes and breaks the current in the primary coil. The current from a battery or from the direct current mains magnetizes the iron core, which attracts the soft iron piece vibrating armature. This motion breaks the current in the primary coil. With the current flow stopped the iron core is demagnetized, and the spring of the interrupting device restores contact of the soft iron piece and thus closes the circuit again ("makes" the current). This process goes on as long as the activating current from the direct current source flows. The tension or voltage of the induced current is considerably higher than that of the inducing direct one; it increases according to the ratio or the number of turns in the two coils. Large faradic coils are known as *induction coils*.

The Transformer.—The transformer is a device changing the voltage in alternating currents. It consists of two coils side by side, having a common "core" of soft iron (Fig. 30); one coil has many turns of fine wire and the other a few turns of coarse wire. When an alternating current is set up in one coil it magnetizes the iron core; it also sets up lines of force which pass through the second coil and an alternating induced current is produced in the secondary coil. The same lines of force cut across one coil as the other. The electromotive force or voltage induced in one coil is directly proportional to the ratio of the number of turns or wire in the coils to each other.

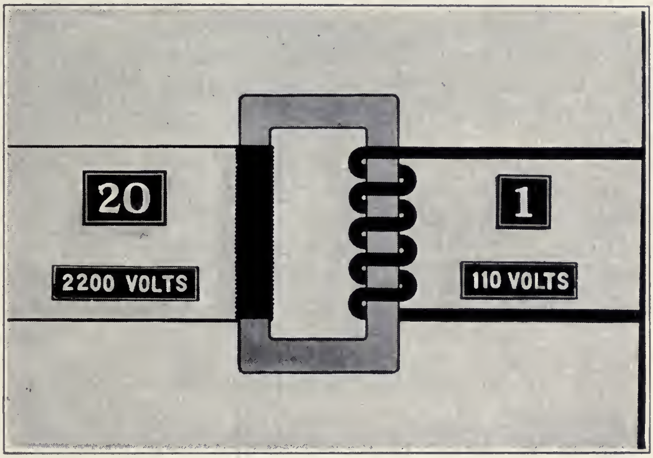

Fig. 30.—Diagram of transformer with iron core.

Alternating currents are easily changed from low voltage to high, or *vice versa*, by means of transformers. In the diagram for instance, it is required to transform 2200 volts down to 110 volts. The fine wire which is connected to the 2200-volt circuit must have 20 times as many turns as the coarse wire coil which is connected to the low-volt circuit. The current in the secondary will be then one-twentieth that in the primary. The energy spent in the secondary circuit is equal to that which the transformer takes from the main line except for a small amount which is lost as heat in the transformer, about 2 or 3 per cent.

There are two kinds of transformers: (1) Step-up transformers, which raise the voltage of the house lighting circuit for use in electrical apparatus, such as high-frequency and roentgen-ray apparatus; in these transformers the secondary coil consists of a correspondingly greater number of turns than the primary coil. (2) Step-down transformers, for the reduction of the high tension alternating current when it reaches the consumer's home, his office or the factory. In these the secondary coil has the lesser number of turns.

The Rotary Converter.—A rotary converter or motor generator is an apparatus for changing alternating current to direct current. A device sometimes used in electrotherapy for changing direct to alternating current is known as an inverted rotary converter. It consists essentially of a dynamo, working either on direct or alternating current, which by a varying of the arrangement of its collecting mechanism—the brushes and commutator—allows the collection of either a direct or an alternating current at the other end.

ELECTRIC OSCILLATIONS AND WAVES

When a spring is bent and released it oscillates back and forth, coming to rest only when its energy is spent. Similarly when a condenser, such as a Leyden jar charged with electricity, is discharged through a circuit of small resistance (an air gap or spark gap), the electron discharge takes place in a back-and-forth rush of current from one charged coating to the other until all the energy is spent in sound, heat, light and electric waves. (Fig. 31.) Such a discharge has been shown to consist of a group of sparks rapidly dying out and is known as an *oscillatory discharge.* With the general employment of thermionic devices (see next section) oscillator tubes have argely replaced the use of the spark gap for producing oscillat ions of various wave-lengths.

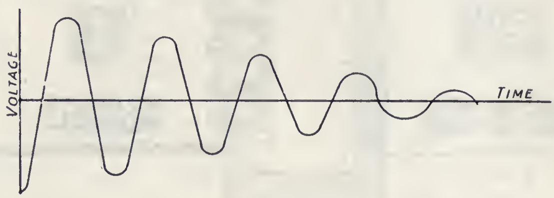

Fig. 31.—Oscillatory discharge of condenser.

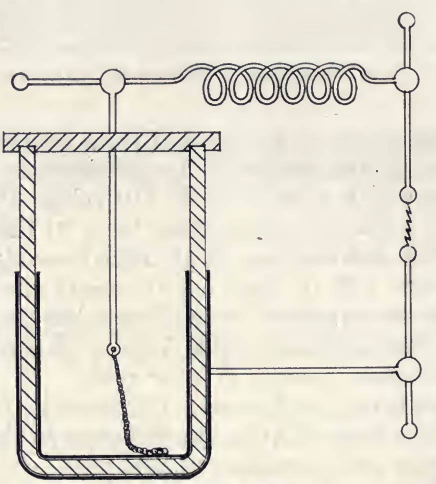

Fig. 32.—Typical oscillating circuit, consisting of condenser (Leyden jar), inductance (coil) and spark gap.

The oscillations produced by the spark gap or by the oscillating tubes are sustained by the inductance, the most essential part of any oscillating circuit. *The inductance* consists of a solenoid, a coil of copper wire. Such a solenoid offers very little ohmic or "conductive" resistance to the passage of a direct current, but offers an enormous "inductive" resistance to the oscillating current which the electrical energy of the condenser discharges. Each turn of the solenoid acts as an impedance to the flow of current; as a result instead of a sudden dying out of the electrical charge, the current oscillates back and forth in the form of wave trains. In the vacuum-tube circuit these wave trains are "undamped" or all of the same amplitude because of lack of internal resistance; in spark-gap circuit they are "damped," *i. e.*, of decreasing amplitude. If there is too much resistance in the discharge circuit there are no oscillations, just as a pendulum hung in molasses will sink to its lowest position without swinging.

The energy of an oscillatory discharge traveling through the air will set up similar oscillations in neighboring circuits, provided they are in "resonance," just as a tuning-fork will excite strong vibrations in a vibrator which is in tune with it. It was shown that these electric waves travel through the air with the same speed as light, 186,000 miles per second, and form part of the huge field of electromagnetic oscillations, which will be extensively discussed in Chapter XV. These oscillations differ in their wave lengths, varying from a mile to a few millimeters, depending on the physical constants of the oscillatory circuit. Wireless telegraphy depends on electromagnetic waves—set up through a spark discharge of a powerful induction coil or high-tension transformer and sent into the air from an aerial or antenna. Electrical waves produced in a spark gap or oscillator tube circuit of an electromedical apparatus are conducted through cords or cables to the body as a *high-frequency* current and employed under the name of long-wave and short-wave diathermy for medical and surgical treatments.

ELECTRONICS

In recent years the use of electron discharge phenomena in vacuum tubes has become quite commonplace, and has played an important part in the development of many technical devices. Some of these, such as the radio, television, and similar commercial devices are well known. Others are of great scientific interest. The cathode ray tube is a vacuum tube electron discharge device which has greatly added to scientific knowledge through visualization of electrical currents. The photoelectric cell has not only been of use to the scientist but is finding increasing commercial application.

More important to us, however, is the thermionic vacuum tube which has found increasing use in electromedical apparatus.

Fig. 33.—Electron discharge from heated tungsten filament.

Thermionic Emission.—Physicists have known for over a hundred years that when a metal is brought to incandescence the air immediately surrounding it became a conductor of electricity. (Fig. 33.) This conductivity is due to the emission or "boiling off" of free electrons from the heated metal. This process is very much like that of the evaporation of water or emission of steam which is caused by the agitation of the molecules of water overcoming the surface tension. In the ordinary electric incandescent bulb the "boiled off" free electrons are drawn back to the filament because when an electron escapes from the metal, the latter is left with a positive charge which attracts the negatively charged electrons. Therefore there are almost as many electrons falling back into the filament as are "boiled off."

While working on the development of the incandescent lamp in 1882, Edison noticed that when he placed a small metal plate in the lamp as shown in Figure 34 and connected this plate to the positive terminal of

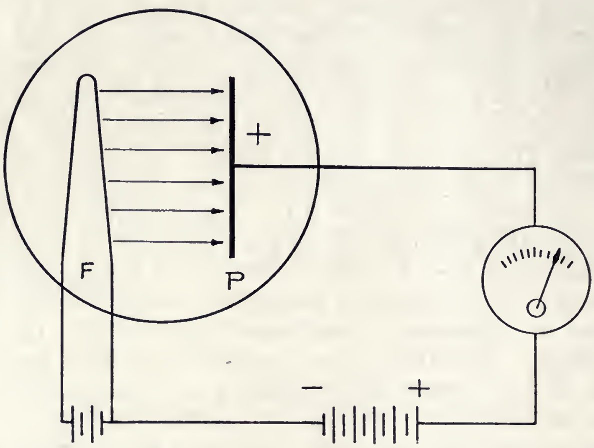

FIG. 34.—Edison Effect I. When plate is connected to positive potential current flows from filament to plate as indicated by the swinging out of the needle of the milliammeter.

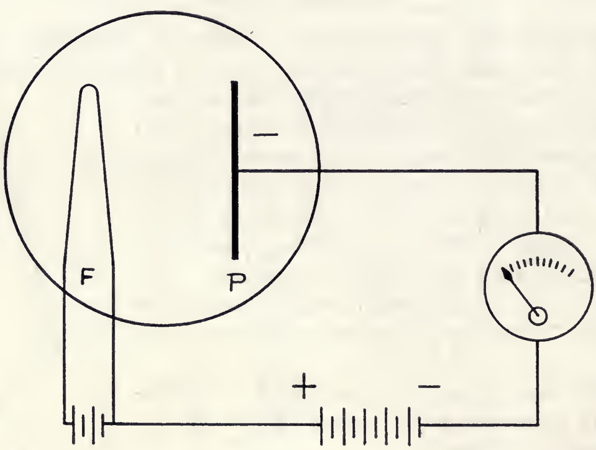

FIG. 35.—Edison Effect II. When negative charge is given to plate no current will flow in plate to filament circuit.

a separate battery known as a "B" battery, a sensitive galvanometer would indicate a current flow. When the plate was connected to the negative side of the battery, as shown in Figure 35, no current would flow. This phenomenon became known to physicists as the "Edison Effect." It remained a physical curiosity but not until the development of the electron theory was it possible to understand the action that took place, and which is now known as thermionic emission.

The explanation of the Edison effect is as follows: If a metal plate is inserted into the bulb as shown in Figure 34 and is connected to a positive terminal of a direct current source called a positive potential—the free negatively charged electrons swarming about the heated filament source are attracted to this positively charged plate; since a moving stream of electrons constitutes an electric current, there will be a flow of current from the plate to the filament. This also can be shown by a galvanometer. If the plate is given a negative charge, as shown in Figure 35, no current will flow because the negatively charged plate will repel the electrons emitted from the filament.

Vacuum-electronic Devices.—The discovery of the principle of thermionic emission led to the construction of a large number of thermionic or vacuum-electronic devices. The main feature of each of these is an evacuated glass bulb known as a vacuum tube and the number and type of metal electrodes contained in it determine its physical characteristics and function.

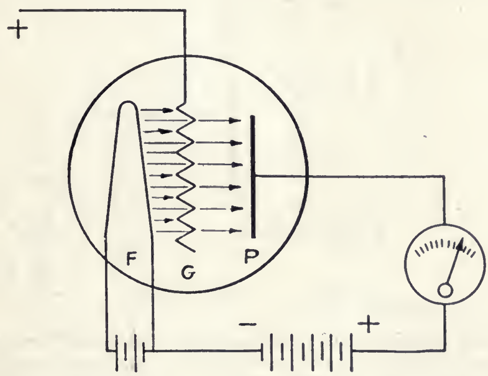

Fig. 36.—Diagram of functioning of amplifier tube. The third element or grid introduced between the filament and plate of the thermionic tube previously shown in Figure 34 serves to influence the current intensity in the plate-filament circuit. A positive potential applied to the grid will increase the plate-filament current as shown by the excursion of the meter.

The *two-electrode tube* or *diode* was developed by Fleming in 1915. It contains a metal filament and a plate. The filament is heated by being connected to a source of current and a second source of current is connected to the plate and the filament. When an alternating current is applied to the plate, a current will flow from the filament to plate only while the plate is charged positively, and no current can flow during the negative phase of the A.C. A tube of this kind will conduct current in one direction only and this action enables the employment of this tube for "rectifying" an alternating current flow, by shutting off every other alternation and changing it into a direct current flow. The vacuum tube acts as a "valve" allowing current flow in one direction only—from the plate to the filament —and the result is an interrupted, undirectional, pulsating current flow. Such a tube is known as a *rectifier* or *valve tube*. It serves to change the alternating current into a direct current by *vacuum-tube rectification*. The rectified current can be further "filtered" by suitable inductance and capacitance until it is made into a smooth galvanic current as produced by an electric cell or battery.

A *vacuum tube rectifier* is a device which employs a valve tube for the changing of alternating into direct current and is widely employed in radio and in various electromedical apparatus.

The *three-electrode tube* or *triode* contains as a third element a fine wire mesh, known as the grid. The purpose of this is to control the flow of electrons from the filament to the plate. The electrons passing from the filament to the plate must pass through the spaces in the mesh, and their passage to the plate is controlled to any desired extent by varying the voltage applied to this grid. If a positive charge is applied to the grid, as shown in Figure 36, it is evident that this positively charged grid will aid the plate in drawing electrons to it. A negative charge on the grid will cause a decrease in the plate current, and if the grid is given sufficiently high negative charge the plate current can be stopped entirely. (Fig. 37.)

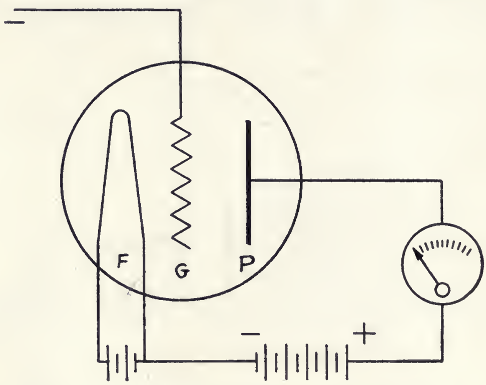

Fig. 37.—Diagram of functioning of amplifier tube. If the positive potential shown in the previous figure is decreased to zero and then increased on the negative side, the current in the plate-filament circuit will gradually decrease and at a sufficient high negative potential will be stopped entirely, as evidenced by the lack of excursion of the meter.

The triode can be used as an *amplifier tube*. From the foregoing it is seen that any variation in the grid potential will be reproduced on a larger scale in the plate circuit. Only a small voltage is needed to obtain changes in the current flowing through the tube. Fluctuations or oscillations of a weak potential cause corresponding fluctuations of a much higher amplitude in the anode current through the tube; in other words, the potential impressed upon the grid is amplified in the anode circuit. The control of the current through the tube, and thus through the circuit of which it is a part, is obtained by applying the potential whose characteristics are to be reproduced on an amplified scale, to the grid and filament. When used in the manner described above, the three-element tube is functioning as an amplifier. If the voltage applied to the grid becomes more and more positive the anode current increases up to a maximum value known as the saturation current. All electrons emitted are attracted to the anode and a further increase of the grid potential makes no change in the voltage or the current.

The triode may also be used as a generator of a very high-frequency current and is then known as an *oscillator tube*. The operation of this device will be discussed in Chapter X.

Gas-filled Electronic Devices.—An electrical current of high voltage passing between two electrodes in a glass tube filled with gas at low pressure causes a glow discharge to take place. This is due to ionization, or breaking up of atoms of the gas and the freeing of a stream of conducting electrons. This differs from thermionic emission of electrons from a heated wire in a vacuum tube. Various colors are produced in the vacuum between the electrodes, depending on the gases ionized. In a neon filled tube the glow discharge is reddish, mercury vapor gives a bluish color, etc. When direct current is used to energize the tube the ionization is brightest near the

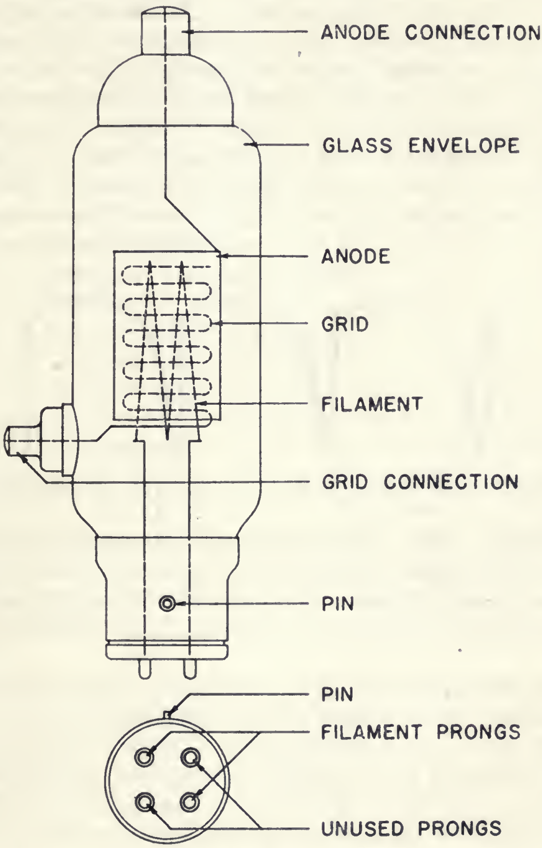

Fig. 38.—Diagram of high-frequency oscillator tube. (Courtesy of Westinghouse X-ray Corporation.)

cathode (negative electrode), when alternating current is used both electrons are equally bright. Mercury vapor tubes used in therapeutic machines for rectification show a glow discharge.

Two-electrode vacuum tubes (diodes) consisting of a heated filament and a metal plate and also containing mercury vapor at low pressure are extensively used as *mercury-vapor rectifiers,* just like thermionic vacuum tube rectifiers: when the plate is negative no electrons are drawn from the cathode and no current flows, only when the plate is positive does the current flow. In electromedical apparatus mercury vapor rectifiers are used in short-wave diathermy machines to convert alternating current from the mains to direct current.

Three-electrode vacuum tubes (triodes) filled with gas are known as *thyratrons*. They are employed because of their ability to carry high voltages and to accurately control not only the voltage flowing through the device but also the frequency of the wave discharge. The larger thyratron tubes contain mercury vapor gas, the smaller ones argon. The tube is usually connected across a condenser with a charging current. While the condenser is absorbing the charging current, the thyratron remains non-conducting, but as the condenser becomes charged, the gas in the thyratron becomes ionized by the rising voltage. When this happens, the tube becomes conducting and short circuits the condenser. The condenser having lost its charge, the voltage drops and becomes too low to maintain the thyratron in an ionized state, so that the tube becomes non-conducting again and the condenser starts to charge once more. (Fig. 39.) This cycle continues, with production of the wave shape shown in Figure 39. The relatively slow rise represents the charging condenser; the sudden sharp drop, the discharge of the condenser by the ionized thyratron tube. When the charging current is held at constant voltage, the rate of oscillation is

FIG. 39.—Wave shape of current produced in thyratron tube.

determined by the size of the condenser. By construction of a unit so that any one of a number of condensers may be introduced into the system as desired, low voltage currents of any desired frequency may be obtained. Extremely simple to control, such currents have perfectly regular wave form.

The Electron Microscope.—This is an electronic device in which a highly specialized vacuum tube is used to reach magnification of tiny objects to a degree formerly considered impossible. In the finest microscope using light and a lens system for its operation, a limit of utility is reached when the object is too small to cover one wave-length of light. This limit can be extended slightly by the use of ultraviolet ray with its shorter wave-length. The electron microscope uses a stream of electrons in place of the beam of light. The usual lenses of the microscope are replaced by a series of magnetic coils which focus the electron stream on the object and then spread it correctly to cover the fluorescent screen or the photographic plate. At present magnification of 25,000 diameters has been accomplished and the limit of the instrument has not yet been reached.

ELECTRICAL CURRENT SUPPLY IN HOMES AND OFFICE

Two forms of current are supplied by central lighting and power stations, the direct and the alternating. The direct current has been more generally employed in cities, while the alternating current at first found more extended use in rural districts. For heating and lighting purposes, both currents are equally satisfactory; for driving of motors, a special A.C. or D.C. motor is necessary, according to the type of supply current; for electroplating and refining, alternating current cannot be used.

For reasons of economy of transmission, the tendency has been in recent years to employ alternating current supply everywhere and in most large cities direct current supply is gradually replaced by alternating current. By generating alternating currents at high voltages (up to 200,000), electric power can be sent over long distances without much loss in transmission, and at any part of the line, the high-tension current can be reduced by a step-down transformer to a low-tension current (110 to 220 volts) ready for general use.

In installing electrical equipment, one should know the kind of current supply in one's locality—direct or alternating—and in the latter case, the number of cycles or periodicity of the current. Both direct and alternating current are equally useful for the ordinary heating and lighting appliances, but when installing motors, ultraviolet lamps, and other forms of electromedical equipment, the kind of current must be known so that suitable types of apparatus can be chosen.

Measuring and Protecting the House Supply.—When the current from the mains enters a building, it first passes through a service switch which permits the entire house to be disconnected from the mains. This switch is fused to protect the house circuits from excessive current flow. From the service switch the current flows through a watt-hour meter where the electrical energy consumption is recorded. The current now passes through the individual circuit fuses to the various outlets and receptacles.

The Rôle of Fuses.—A fuse is a current-limiting device, consisting of a piece of alloy of low melting-point and of such thickness and length which is calibrated to stand just a certain amount of current. If more than the contemplated amount of current is drawn the wire rapidly heats up and melts, the fuse blows and the flow of current is interrupted, thus preventing overheating of electric wires or sparking and the consequent danger of a fire.

Fuses will blow most frequently through overloading or through a short circuit. Overloading occurs when more current is drawn than is allowed a given circuit. For instance, if a branch circuit is wired and fused for 15 amperes at 100 volts and one turns on a 1000-watt bulb drawing 10 amperes and then tries to light an ultraviolet generator drawing about 9 amperes on the same circuit one is usually reminded, to the tune of a blown fuse, that the limit allowed has been exceeded. Needless to say, replacing the 15-ampere fuse by a 25-ampere fuse does not solve the problem, as the capacity of the fuse and the wiring in a given circuit are related, and by attempting to draw more current one overheats the entire wiring and courts trouble and danger possibly in some inaccessible part of the circuit. To prevent overloading the number of outlets and the wiring in a given circuit, therefore, one must never use a fuse larger in capacity than the maximum amount of current to be drawn.

Short circuits occur if somewhere in a circuit two insulated wires come into unexpected contact, as will happen when the insulation in a conducting cord is worn away or one wire in an attachment plug becomes loose and touches the opposite one. This causes an arcing of the current across the short path, and on account of the lessened resistance more current is drawn and, consequently, the fuse blows. A short circuit is by far the most frequent cause of blowing of fuses in the physician's office. Its prevention lies in inspecting all contact parts subject to friction and strain, either at stated periods or whenever they show wear. If a fuse has blown, before replacing it one should disconnect the piece of equipment in which the short circuit has occurred; otherwise the fuse will blow again. The hissing noise, sparks and heat accompanying a short circuit usually makes its location easy.

Finally, fuses may blow at times without apparent reason, due perhaps to wear of equipment or to defective construction. In such instances they have simply to be replaced. Fuses are sometimes made part of electrical apparatus, in order to protect delicate lamps and measuring devices against any excess of current.

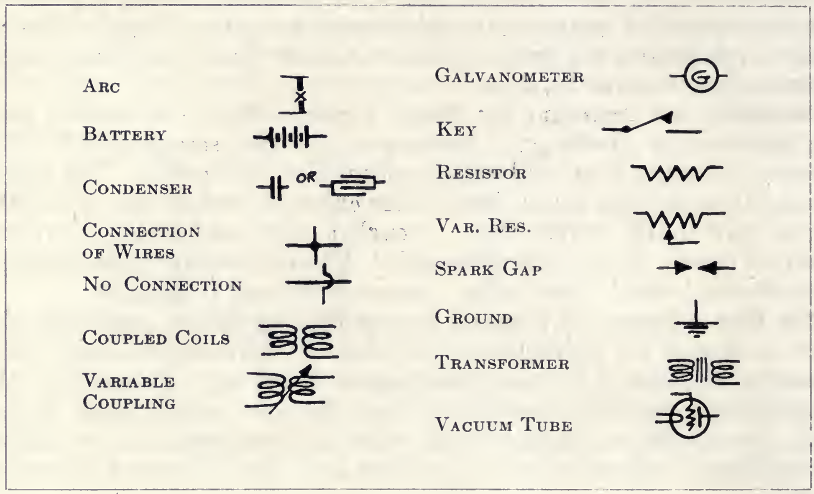

Fig. 40.—Electrical symbols most frequently employed.

Locating Trouble.—In order to be able to act at once in case of fuse or other trouble, anyone employing electricity for therapeutic purposes should know the location of the fuses for each circuit and also on the apparatus itself so as to be able to replace them *after* the cause of the trouble has been found and eliminated. It is advisable that a panel box with all fuses pertaining to the equipment should be located in or near the office at a place easily accessible and well lighted. A complete diagram affixed to the inner door of the fuse box should show the outlets covered by each of the fuses and thus make quick repair possible. It is also advisable to have the lighting circuit of the office separate from the therapeutic circuit, so that in case of trouble the lights would not be disturbed, the light sockets even serving as an emergency supply socket for the apparatus. A sufficient supply of fuses of appropriate size should always be kept on hand in the fuse supply box, along with an electric flashlight in working order, or a piece of candle and matches.

A simple trouble-testing outfit consists of an insulating electric socket with an incandescent bulb in it. The two wires leading into the socket should be well insulated and are cut off at about 1 foot distance; but their ends for about ½ inch should be bare so that, by simply placing these two ends over another bare metallic surface, good electric contact can be established. By doing this with fuse blocks, the feed bars of the fuse box, lamp sockets and conducting cords, the presence or absence of current can be instantly detected by the lighting-up of the test lamp or by its absence. In fuse boxes equipped with the modern type of fuses, made of glass, a simple glance at the discolored central portion of a fuse shows that it has blown.

If more than one circuit has failed in the house as, for instance, a number of pieces of apparatus and the lights on several floors, this usually indicates that one of the main fuses in the meter box has blown or that the trouble may be in the meter or in the supply line outside of the house. In such case the help of the electric power company should be summoned.

In recent years the use of the thermal operated circuit breakers (cut-outs) to replace fuses has become popular. The advantage of this device is that it need only be reset after it has operated and after the cause of the overload has been corrected. Magnetic circuit breakers are also favored in some installations.

Current Outlets.—For the efficient working of electrotherapeutic equipment, the proper number and placing of current outlets is both a convenience and a necessity. Starting from the fuse box, each electrical circuit in the home or office includes several outlets, either as base plugs or wall receptacles. A temporary connection to any electric light socket may be permissible for small apparatus provided that the outlet is wired and fused for the amperage of the particular apparatus. For permanent connections, special outlets, preferably independent of the lighting circuit, are advisable. These should be placed about 3 to 4 feet above the floor so as to be readily accessible for attachment of the connecting line to the apparatus. The number of outlets should correspond to the pieces of equipment; frequent plugging in and out causes unnecessary wear and tear on the connections.

If both alternating and direct current supply is available it is advisable to have an outlet for each kind—well marked—alongside of each other; where there is only direct current available all outlets should be marked for proper polarity (+ and −), or else the connecting cable of any piece of equipment should be marked so that it is inserted in the same way each time; this will insure that the polarity of current supply remains unchanged.

PART II

General Electrotherapy and Electrodiagnosis

CHAPTER IV

ELECTROMEDICAL CURRENTS, APPARATUS AND ACCESSORIES

General Considerations. Classification of Currents. Currents of Low Tension and Low Frequency. Currents of High Frequency. Static Electricity. Electromedical Apparatus. Typical Features. Conducting Cords and Cables. Electrodes. Miscellaneous Accessories.

General Considerations.—Electromedical currents are practically all derived from the commercial lighting circuit. The galvanic current may be drawn *directly* from dry cells or radio batteries and also with an interposed resistance from the direct lighting current. All other currents are obtained *indirectly* from the direct (D.C.) and much more frequently from the alternating (A.C.) street current by suitable modification, through motor generators, transformers, and other electromagnetic or thermionic devices.

The source and means of production of any current has but little relation to the response of the tissues of the body. The final form of the electrical energy, the technique of application and the individual equation of the subject will determine the effect that it will exert.

TABLE 5.—COMPARISON OF WATER SYSTEM AMD ELECTRIC CURRENTS

Water system	Electric current
Low pressure	Low tension galvanic, sinusoidal
High pressure	High tension: static, high frequency
Fine spray	Low amperage: static, faradic
Large volume	Large amperage: diathermy
Continuous flow	Galvanic current
Squirts or waves	Interrupted and surging currents

The transformation of the basic electrical energy into the different therapeutic currents is best visualized by the simile of a water system. Water can be applied either at high pressure or at low pressure, at a large rate of flow or in a fine spray, running continuously or in abrupt squirts or waves. Similarly the flow of electrons may be even, or be interrupted, or reversed, frequently or infrequently, symmetrically or asymmetrically; the rate at which the current is increased from zero to maximum may be slow or rapid and it may remain at low tension or rise to very high tension.

CLASSIFICATION OF CURRENTS

In classifying electromedical currents, their primary characteristics as well as their biophysical effects are taken into consideration.

TABLE 6.—ELECTROMEDICAL CURRENTS I—PHYSICS
Physical Characteristics

Current	Mode of flow	Approxim. frequency	Voltage	Amperage	Physical effect
Galvanic	Unidirectional constant	...	Low	Medium	Chemical
Interrupted and surging galvanic	Unidirectional surge	Up to 100 per sec.	Low	Medium	Chemical and electrokinetic
Slow (galvanic) sinusoidal	Slow alternating waves	3 to 90 per min.	Low	Medium	
Interrupted sinusoidal or mod. alternating	Rapidly alternating waves	Up to 180 per sec.	Low	Medium	
Faradic	Rapid asymmetric alternating surges	About 100 per sec.	Medium	Low	
Long-wave diathermy	Extremely rapid oscillations	1,000,000 per sec.	High	High	Thermal
Short-wave diathermy	Extremely rapid oscillations	10,000,000 per sec.	High	High	Thermal
Static wave and spark	Unidirectional surges	About 100 per min.	Very high	Very low	Electrokinetic

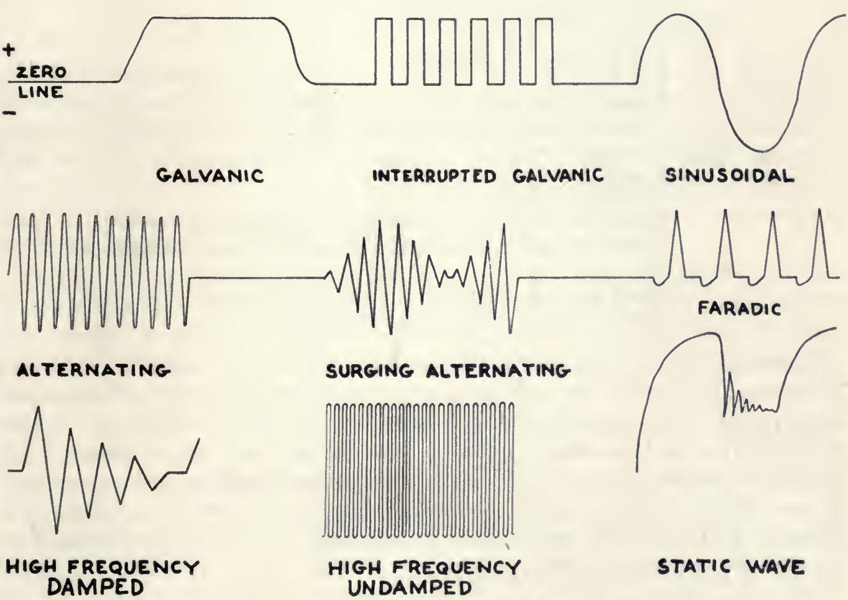

FIG. 41.—Diagram of principal electromedical currents (not to scale).

The physical characteristics of electromedical currents are direction of flow or frequency of alternation, voltage or strength and amperage or volume of flow. The following groupings can be made on the basis of these:

1. **Direction and Frequency of Flow.**— *Unidirectional currents* are those which flow in one direction without reversal of polarity; the galvanic

current, the interrupted galvanic, and the static modalities are unidirectional currents. *Alternating* currents are those which reverse their direction of flow; this group includes: (*a*) *low-frequency currents* with an alternation not exceeding several hundred per second; the faradic, the slow sinusoidal and the modulated alternating current belong to this group; (*b*) *high-frequency currents* with alternations or oscillations over 1,000,000 per second; long- and short-wave diathermy belong to this group.

2. **Voltage or Tension.**—*Low-tension* currents are those with a voltage of 100 and less; the galvanic and the low-frequency currents belong to this group; *high-tension* currents are those with a voltage of several hundred or higher; high-frequency currents and static electricity are among these.

3. **Amperage or Volume.**—Since no high amperage or current volume is possible without a corresponding high voltage to produce it, generally speaking high-voltage currents are currents of high amperage, employing from 500 to 2000 or more milliamperes while currents of low tension are currents of low amperage, employing from 1 to 30 milliamperes. The static current occupies a unique position inasmuch as it represents a current flow of very high voltage—to several thousand or more, but its volume of flow is minimal, less than a milliampere.

TABLE 7.—ELECTROMEDICAL CURRENTS II—PRINCIPAL FORMS OF APPLICATION

- The galvanic current
  - Medical galvanism
  - Ion transfer
  - Surgical galvanism (electrolysis)
- Currents of low tension and low frequency
  - The interrupted galvanic current
  - The faradic current
  - The slow (galvanic) sinusoidal current
  - The modulated alternating current
- High-frequency currents
  - Long-wave diathermy
  - Short-wave diathermy
  - Monoterminal high-frequency sparking (Oudin current)
  - Electrosurgery: desiccation, coagulation and cutting
- Static electricity
  - Static wave and sparks, static induced current
  - Static brush discharge, static bath

According to biophysical effects, electromedical currents can be divided in two large groups: (1) currents causing ionic changes in the tissues and a minimum of thermal effects, (2) currents causing only thermal changes. The galvanic and low-frequency currents belong in the first group, high-frequency current in the second. Static electricity again occupies a separate group. Table 7 shows the generally accepted grouping of electromedical currents and their principal forms of application. All these will be fully presented in their respective chapters.

ELECTROMEDICAL APPARATUS

The average physician, no better than the average layman, looks upon apparatus either as something mysterious, ready to perform curative feats by the turn of a knob, or else thinks it is all make-believe. As a matter of fact, all that apparatus can do is to deliver a definite form and amount of physical energy to a given part of the body. It is up to the physician to know what physiological effects to expect from such an application and when to make use of it in treating disease and injury. The physician should be able to visualize at all time: (1) the physical events inside of the apparatus when the current is turned on from the source of electric power and (2) the physical and physiological changes in the body when the current is applied through the electrodes.

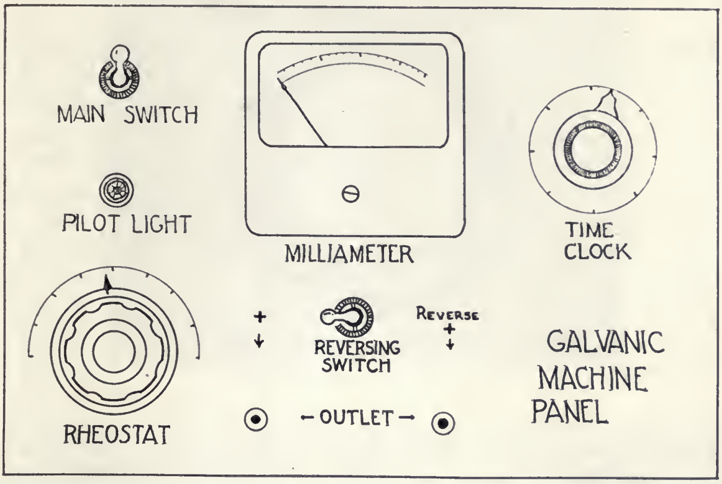

FIG. 42.—Diagram of control board of simple galvanic apparatus.

Typical Features of Apparatus.—Electrical apparatus for treatment purposes usually consist of a box or cabinet, which contains the electrical unit (motor transformer, vacuum tubes, etc.) changing the supply of alternating lighting current into one of the electromedical currents. Some pieces of apparatus contain dry cells or batteries and are independent of any outside current supply source. All switches, knobs and terminals are mounted on insulating material, such as hard rubber or porcelain.

The typical features of the average apparatus are: (1) A *current inlet* where the cable bringing the supply current from a wall receptacle or light socket is inserted. (2) A *main switch* by which the flow of supply current is turned on or off. (3) A *rheostat* or regulator which regulates the strength of the incoming current and enables the drawing of as much current as is needed for the individual treatment. (4) A *milliammeter*—or simply meter—showing the amount of current passing. (5) *Terminals* or current outlets for the insertion of cables or conducting cords which lead the current to the patient. According to the type of apparatus, there may also be other controls such as illustrated in Figure 42. (6) a *pilot* light, which lights up as soon as the main switch is turned on and the supply current enters the apparatus, and (7) a *timing device* (time clock) by which the current flow can be set from a few minutes to an hour; at the end of this period the current is automatically cut off.

CONDUCTING CORDS AND CABLES

The electrical energy from electromedical apparatus is conveyed to the patient by means of conducting cords, or cables, consisting of flexible copper wire surrounded by a suitable rubber insulation. The thickness of insulation depends upon whether a current of low or high voltage is carried by the conductor.

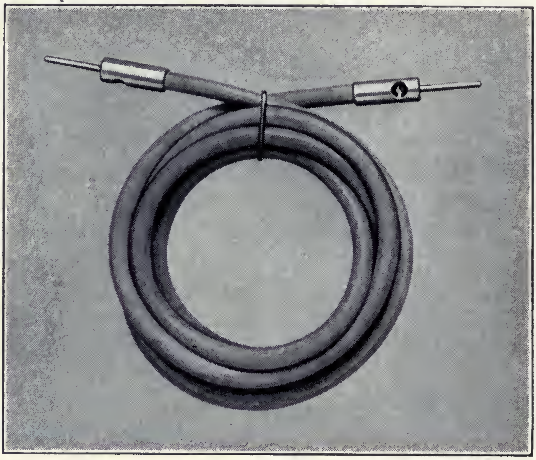

Fig. 43.—Conducting cord.

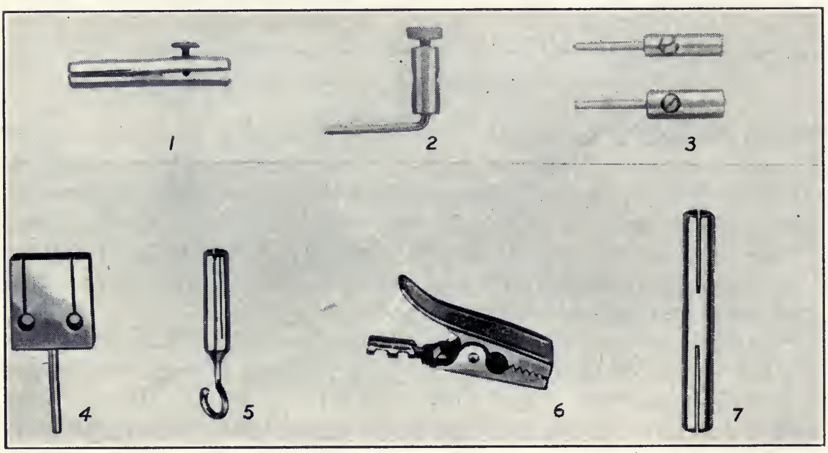

Fig. 44.—Connectors and cord tips. *1*, single flat connector for cord tip; *2*, bent connector for binding post on apparatus; *3*, cord tips; *4*, double connector for binding post; *5*, hook connector for vacuum or condenser electrode; *6*, spring connector; *7*, double connector to lengthen cords.

Conducting cords used in present-day equipment are, as a rule, of uniform color and serve for the conduction of both low-tension (galvanic-faradic-sinusoidal) and high-tension (long-wave diathermy) currents. Special cables serve for short-wave diathermy. For galvanic treatment sometimes cords with different coloring of their insulating cover are employed so as to remind the operator of the different polarities. Conducting cords must be fastened securely at one end to the binding post of the apparatus, usually through a binding screw; on the other end to the electrode, usually through some clip arrangement. Supporting the cord along its way from the binding post will minimize the danger of its pulling out of the clip.

For fastening conducting cords to the back of the metal electrodes *clips* or flexible connectors serve. In low-tension moist pad electrodes a connection for the conducting cord is usually soldered onto the metal back, and the cord tip is held there by a spring. All such connections are subject to electrolytic deterioration and breaking and should be inspected from time to time. Loose-fitting clips may pull out easily, causing an excess density of current on the skin and an instantaneous burn if they should touch the bare skin.

Cords may get out of order by a break of the copper wire inside of the cord's insulation; or by loosening or slipping of the contact between the wire and metal tip. To prove that the current goes through a cord one may connect the terminals of an apparatus by the cord and turn on a very small amount of current. If the wire is intact and conduction is present, the meter will register current at once (be careful not to strain meter by sudden heavy current). Cords when not in use should be hung up and not rolled up; this will prevent the breaking of the fine copper wire. Loose contact between the wire and the cord tip is remedied by scraping off the insulation at the end of the cord and reapplying the copper wire by tightening it with the binding screw. To prevent loosening at the cord tips, cords should never be jerked out of the sockets but gently pulled out by holding on to their tips.

Conducting cables for short-wave diathermy consist of heavy insulated cables containing the conducting wires. Short-wave condenser pads carry a cable attached to one corner, and the other end of this cable plugs into the treatment outlets of the apparatus. These cables are shorter than conducting cords for long-wave diathermy; they form part of the treatment circuit. When they are in contact or close to a good conductor (metal frame of bed or chair) or when crossing each other they may concentrate some of the electrical energy; such energy leakage heats up the rubber insulation of the cable and may cause it to burst into flame. The most vulnerable part of the cable-pad electrode assembly is the corner where the cable joins: due to careless handling the rubber insulation may crack there and lead to leakage of current and subsequent overheating. Regular inspection of such accessories is, therefore, essential.

ELECTRODES

An *electrode* is a medium intervening between an electric cord or cable and the body. It should consist of a good conducting material, the shape and form of which can be well adapted to the skin or the cavity.

Water containing some salt is the simplest electrode material and makes perfect contact with an extremity immersed in it. The water bath as an electrode is used for some galvanic treatments and also may be used (Fig. 175) for long-wave diathermy treatments to hands and feet. For the great variety of electric treatments, however, most of the electrodes consist of flexible metal plates, either directly applied to the body or separated by moist padding or rubber insulation. Glass vacuum electrodes are used for certain high-frequency treatments.

Contact metal electrodes are cut to suitable size and shape from electrode foil—an alloy of lead, tin and zinc. Metal electrode material comes in three grades of thickness and is sold in rolls by the pound. It is cut by shears into suitable sizes, and it is advisable to leave a small tongue, about 1 by $\frac{1}{2}$ inch to one side; folded back against the rest of the plate this tongue serves for attaching the conducting cord. Before use the electrodes should be smoothed out by a light roller like used for photographic prints. They should be cleansed from time to time with soap and water. Plain metal electrodes are chiefly used for long-wave diathermy treatments.

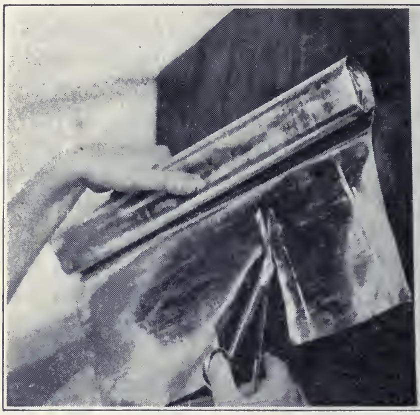

FIG. 45.—Cutting electrode foil.

FIG. 46.—Plate electrode ready for use.

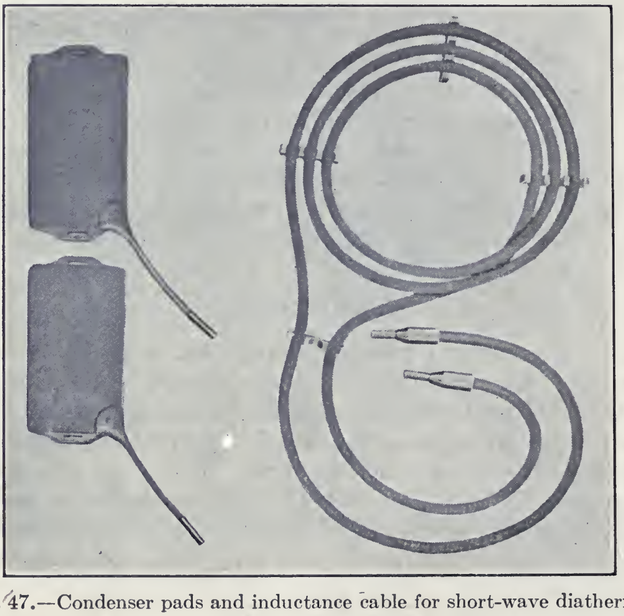

FIG. 47.—Condenser pads and inductance cable for short-wave diathermy.

Spaced metal electrodes (condenser pads and cuffs) consist of flexible metal enclosed in insulating rubber sheath. They are applied to the skin with an interposition of toweling or felt, and additional moisture-absorbing blotting or tissue paper. Spaced plates consist of metal discs enclosed in hard circular rubber treatment drums or cylindrical glass "shoes." They are held at a suitable distance and position by adjustable wooden arms. All these electrodes carry a fixed cable connection in one corner and serve for short-wave diathermy treatments.

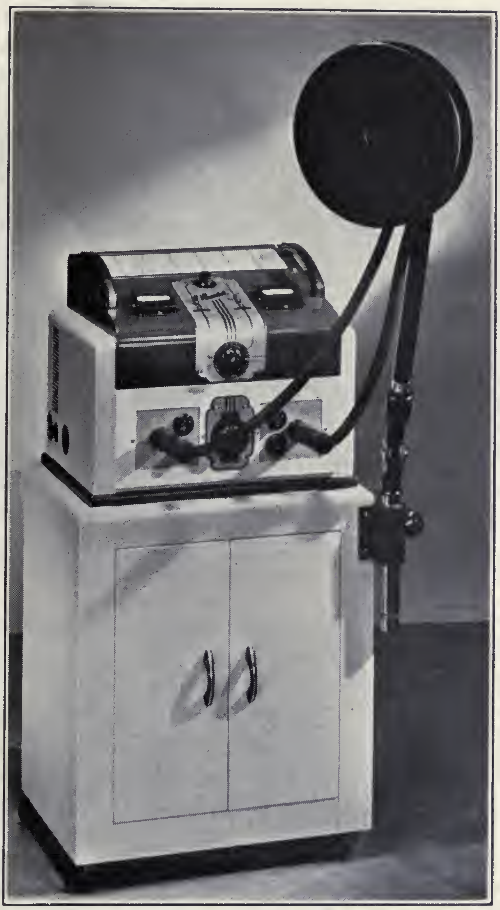

FIG. 48.—Short-wave diathermy apparatus with treatment drum. (Courtesy of Burdick Corp.)

Inductance cables are single electrodes used for short-wave diathermy with the electromagnetic field technique. They contain a flexible wire surrounded by heavy insulation. They are applied in the form of circular loops around the body or an extremity and also in the form of a "pancake" coil or a treatment drum. Their two ends carry plugs to fit into the current outlets of the apparatus.

Moist-pad electrodes consist of flexible metal plates covered on one side with a layer of soft rubber and bearing a suitable opening for the attachment of the conducting cord. On the side to be applied to the skin there is a pad of absorbent material of suitable thickness and strength, such as asbestos, and this is covered with linen, fastened to the metal plate in back.

Moist-pad electrodes serve for galvanic and low-frequency treatments in which it is necessary to soften the horny layer of the skin for the passage of the current. The covering of the pad electrodes is soaked with tap water or a 2 per cent saline solution. The moist pad also absorbs the acid or alkaline products of the electrical decomposition of the metal and thus prevents chemical burns. The ordinary one-piece pad electrodes can be easily cleansed by soap and water, and laid out to dry until the next use. A simple method to provide a clean surface at each treatment is to cover the pad with a fresh layer of loose sterile gauze.

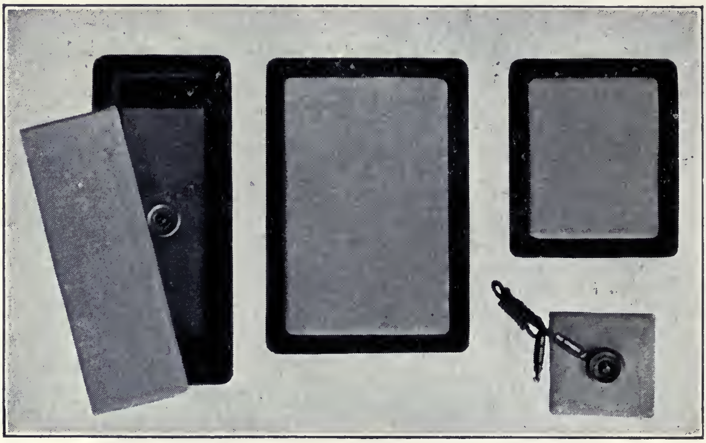

FIG. 49.—Pad electrodes for low-tension currents. The removable asbestos pad allows better cleansing. (Courtesy of Burdick Corp.)

Instead of ready-made moist pad electrodes electrode pads of any desired size for galvanic treatments can also be improvised by folded hand towels, Turkish towels or cellucotton. In such case care must be taken that the material used be of adequate thickness and is thoroughly soaked in saline solution, that it is well folded and that the metal foil laid on top of it should nowhere come in contact with the skin, also, that the conducting cord is well fastened to it by a clip and is safely held there.

FIG. 50.—Small pad electrode for muscle stimulation.

Glass electrodes serve for the application of some forms of high-voltage (high-frequency) treatments to the body. They are made in two types: *Vacuum* electrodes consist of a hollow glass tube from which the air has been exhausted to a varying degree. *Condenser* electrodes are made of especially heavy glass, the inner surface of which is lined with silver; they contain air at ordinary atmospheric pressure. Glass electrodes are mounted on an insulating handle to prevent the leakage of current through the operator's fingers. No current ever passes directly through the glass wall; the rapid charging and discharging of the inner surface of the tube to which the current is led, induces charges of opposite character on the outer surface through the glass.

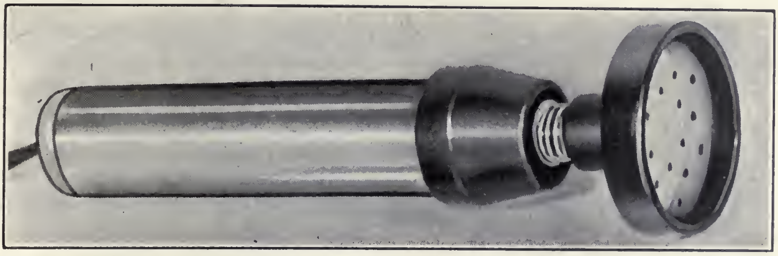

Fig. 51.—Bipolar electrode, especially useful for galvanic treatment of one eye. Cup filled with moist cotton forms one pole, when held against the closed lid; the handle forms the other pole. (Courtesy of Teca Corporation.)

Orificial electrodes of various shapes and sizes are made of metal—copper, zinc, etc.

Securing Electrodes.—Electrodes have to be applied and held snugly. Under the back and the chest, etc., the weight of the patient's body will hold the electrodes, while over the thigh, abdomen and front part of the chest, a small sandbag and pillow can be utilized to hold the electrodes

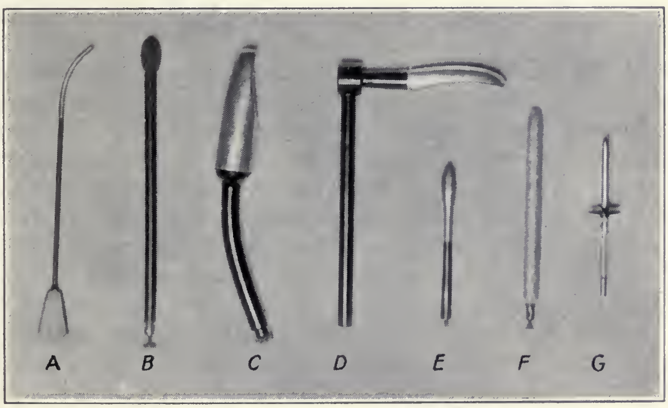

Fig. 52.—Metal orificial electrodes. *A*, cervical copper electrode; *B*, carbon-tipped vaginal electrode; *C*, metal vaginal electrode; *D*, metal prostatic electrode; *E*, metal rectal electrode; *F*, cylindrical rectal electrode; *G*, electrode for female urethra.

with the patient recumbent on his back. In applying electrodes over an extremity, the face, or other rounded portion a few turns of a woven elastic bandage, 2 inches wide, will insure an even contact. In bandaging moist pad electrodes it may be advisable to interpose oiled silk between the electrode and the bandage in order to prevent diffusion of the current due to the wet bandage, or else to use a rubber bandage.

For the safe retention of the electrodes, when not held by the operator, devices consisting of a stand, arms and clamps are available. In rectal and vaginal applications sandbags are usually sufficient, holding the electrode in a secure position. Some electrodes are mounted on insulated handles, made of wood or vulcanite, and the handle is fitted with attachments to make, break, or otherwise regulate the current. Electrodes with handles permanently attached or removable are used mainly for short applications to small areas, such as in testing for electrical responses of muscles and nerves and also for treating weak or paralyzed muscles (motor point treatment).

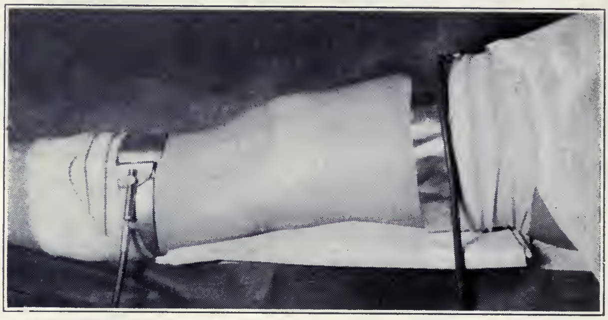

Fig. 53.—Metal cuff electrodes above and below knee. Secured by bandaging.

Further details of different electrodes, their handling and securing will be found in the chapters on the various currents.

MISCELLANEOUS ACCESSORIES

Treatment Timers.—For the accurate measuring of treatment time, and as an added feature for safety of application, special alarm clocks or automatic clock turn-offs are well nigh indispensable. These clocks can be set usually for any number of minutes, from one to sixty. Anyone practicing physical therapy should at the very start acquire the habit of setting a clock for the treatment period for each patient. This will avoid occasional situations when, on account of an absorbing telephone conversation or some other distraction, a patient may be left connected too long to a machine or under a lamp.

For a visual timer signal a 120 volt lamp of very low wattage (3 to 7) may be connected across the timer as suggested by Dr. Jerome Weiss. While the machine is operating, the closed timer switch will act as a shunt across the small lamp. When the treatment time is up, and the timer switch opens, the small lamp will be in series with the machine. The lamp will light almost to full brilliancy, but the current flowing through it is not sufficient to operate the machine. If several machines are in use at the same time, this visual signal will call the attention of the operator to the particular one which has completed its treatment time. In installations where many treatment booths are used, the signal lamp may be placed at the entrance of the booth where it will be visible to the operator in any part of the room.

Patient's Release.—A patient's release consists of a cut-off switch which can be operated by a gentle pull of a cord placed within reach of the patient. It will immediately reassure a patient who is apprehensive of an electrical treatment if he knows that he can turn off the current at any time without even calling for the doctor. As a matter of fact, with skilfully applied electrodes and proper dosage of current there will hardly ever be any occasion to utilize such release except in a real emergency, like the slipping of a cord tip or dislodging of an electrode due to an untoward movement of the patient.

Foot Switches.—For the application of treatment where both hands of the operator are needed, as in the surgical application of high-frequency currents, it is important to be able to start or cut off the current by a foot switch. For the application of the monoterminal high-frequency current the foot switch is serviceable because by its use one may eliminate the unpleasant leakage of the high-voltage current from the conducting cord each time the electrode is lifted off the patient while the current is on.

The development in the technique of the various electrical modalities brings forth constantly minor and major innovations in accessories of treatment. A study of the latest catalogue of manufacturers furnishes always a good deal of up-to-date information about these developments.

Fig. 54.—Automatic treatment timer and patient's release. (Courtesy of the General Electric *X*-ray Corporation.)

Treatment Tables and Couches.—Well-built tables or couches are essential for the efficient administration of electrical and light treatments. A wooden table, 26 inches high, 24 inches wide and 60 inches long, with upholstered top and with a head-rest, is the most desirable when it has to serve for all treatment. It is suggested that either the head or the foot end should be adjustable. Patients with stiff backs or extensive arthritic changes prefer a low couch, and this is also more convenient for light treatments, as it allows a greater range in adjusting the distance of the lamp from the patient. For knee and foot cases an armchair with an adjustable foot-rest, like a steamer chair, is quite convenient. Metal tables, as a rule, are not desirable on account of the possibility of grounding the current. For further details of office equipment see Chapter XXXVII.

CHAPTER V

EFFECTS OF ELECTROMEDICAL CURRENTS. PASSAGE THROUGH THE BODY. GENERAL RULES OF TREATMENT

Primary Physical Effects. Ionic Effect. Thermal Effect. Specific Electric Effect. Secondary Physiological Effects. Psychological Effects. Electrical Conduction Through the Body. Resistance of the Skin. Resistance to Different Currents. Practical Importance of Skin Resistance. Changes in Skin Resistance. Path and Strength of Currents Through the Body. Current Density. Influence of Size and Position of Electrodes. General Rules of Electrical Treatment.

In medical electricity electrical energy of sufficient strength and duration is applied to the body, in order to exert certain physical effects, known as "primary" physical effects. These in turn affect cellular activity and produce "secondary" physiological changes. The rationale of clinical use is based on these effects.

Primary Physical Effects.—The human body consists of a composite mass of tissues which have electrical constants like any other substance or matter, *i. e.*, all of them act as conductors of electricity to a varying extent. In human tissues all cells are bathed in lymph or other intercellular fluid and an electric current, in order to reach the cells, has to pass through this fluid. The tissue fluids consist of a solution of water, albumin, fibrin and salts. Hence the problem of electrical conduction in the tissues can be regarded as a problem of conduction in an electrolytic solution of a somewhat complex character. An electrolytic solution contains dissociated atoms of the component particles of acids, bases or salts. These free atoms or ions all contain an electrical charge; bases, metals and alkaloids are electropositive and acids and acid radicals electronegative.

The two principal primary effects of electricity on living tissues are the ionic or chemical effect and the heating or thermal effect. Generally speaking, ionic effects are exerted by the galvanic and low-frequency currents, while a primary heating effect is exerted by high-frequency currents. Both of these effects are based on electrolytic conductivity of tissues; a current passes through an electrolyte because the electrically charged particles are the sole carriers of the electric charge. The method of short-wave diathermy has added a new form of thermal effect on the basis of dielectric "conductivity." Static electricity occupies a special position by exerting so-called partly ionic and partly purely electrokinetic effects, the physical explanation of which is not as clear cut as that of ionic and thermal effects.

1. **Ionic Effect.**—When a direct (galvanic) current passes between two electrodes immersed in an electrolytic solution, positive ions will be attracted toward the negative pole and negative ions toward the positive pole. The same "common ion transfer" or *electrophoresis* will take place in human tissues and since the ionic concentration is quite different inside of cells and the surrounding tissues and fluids, there must come about some changes in the ionic balance.

In addition to simple transportation of ions, two further forms of ionic movements take place in the composite medium of tissues: (1) *Cataphoresis* is the transportation of non-dissociated molecules and colloids, due to the adsorption of these particles by the electrical ions; it has been shown to proceed always from the positive to the negative pole. (2) *Electroösmosis* is the shifting of the water content through an electrical or membrane structure with an electrical charge. These effects in their totality may be described as electrokinetic phenomena. (See Chapter VIII.)

It is evident that these somewhat complex ionic and electrokinetic phenomena must lead to a variety of secondary chemical and colloidal processes, the extent of which may be often difficult to ascertain. There may be possible changes in the local metabolic processes, or changes of permeability and a consequent alteration in metabolic exchange.

If there is a concentration of ions of sufficient intensity at a definite point (motor point) there arises a stimulation of muscles and nerves with a resulting muscular contraction. Such stimulation is effected by the various low-frequency currents and is the basis of one of the most important electrotherapeutic procedures. It enables well controlled stimulation of one muscle or a group of muscles whether normal or paralyzed.

There is no ionic concentration and subsequent muscle and nerve stimulation with high-frequency currents, because of their extremely rapid oscillation through the tissues; the duration of each single impulse is much below the effective time for ionic concentration.

2. **Thermal Effect.**—All electrical currents develop heat in their path according to Joule's laws. (Chapter II.) The strength of the direct or alternating current used in ordinary treatment, though sufficient to produce ionic effects, is not sufficient to produce a physiologically active amount of heat. An alternating current of high voltage as used in electrocution does produce enough heat to coagulate the tissues under the electrodes and raise the body temperature appreciably.

A high-frequency current brings about a rise of temperature of the tissues in accordance with its frequency, strength and duration. Subsequent biological changes in the tissues are secondary to this primary physical effect.

The flow of high frequency electric energy through the body tissues varies with the frequency of the current. High frequency currents of long-wave length and relatively low frequency encounter a "load" in the tissues which is predominantly "resistive." Therefore, the major part of the heat production in long-wave diathermy occurs by virtue of the conductivity of the tissues. (Fig. 55.)

High-frequency currents of short-wave length and relatively high frequency encounter a load which is mostly "capacitative." (See later under Electric Conductivity.)

With both forms of high-frequency heating rise of local and general body temperatures within the limits of physiological toleration can be produced. According to the temperature law of Van't Hoff, for every rise of 10° C. the rate of oxidation is increased 2.5 times, and thus even temperature changes of tenths of degrees will influence cellular oxidation and exert marked effects on physiological processes.

Conductive and convective forms of heating (hot water, heated solids, hot air) heat the tissues from without inward by conduction from the skin surface in contrast to the through and through heating of diathermy. Heat effects of high-frequency electrical currents are one of the major procedures of modern electrotherapy because of the penetrating and well-controllable heat production.

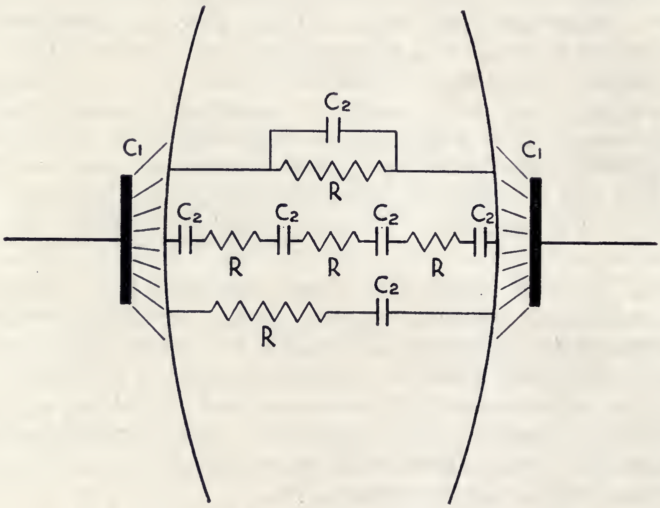

FIG. 55.—Schematic illustration of passage of short-wave diathermy current from condenser pads C_1 through section of human body partly as a current of conduction (through ohmic resistances R) and partly as a current of capacity (through dielectric substances C_2). These resistances and capacities are both in series and in parallel.

Specific Electrical Effects.—There are a number of reports on record that the electrical current exerts certain physical effects on the cellular contents of the human fluids, which cannot be classified as either ionic or thermic. Galvanotaxis of leukocytes, described in 1891 by Dineer, consists of an attraction of normal leukocytes by the anode of a galvanic current, while leukocytes of inflamed tissues are attracted to the cathode. According to Monguio[8] the reversal from cathodal to anodal galvanotaxis depends on the internal condition of the cell. With the alternating currents, effects of oscillotaxis and oscillotropism have been described by Scheminzky and Scheminzky.[10] With higher frequencies Muth observed in 1927 that in the alternating current field of 2.10^4 to 2.10^6 pearl chains are formed in fat emulsions, *i. e.*, the fat globules arrange themselves in a way that their central points are in parallel with the field. Krasny-Ergen[3] confirmed that these pearl chains are also formed with ultrashort waves of very weak energy—excluding thermal effects which would make fat globules boil. Liebesny[5] actually demonstrated these effects. (Fig. 56.)

The rôle of these specific electric effects in our therapeutic procedures is doubtful but their existence is interesting enough to be placed on record.

Destructive Effects.—Any form of physical energy is capable of producing destructive effects when applied beyond the limits of physiological toleration. The well-controlled employment of such destructive effects is the basis of the various procedures of electrosurgery. (Chapter XIII.)

Table 8.—Scheme of Physical and Physiological Effects by Electrical Currents

Current	Primary physicochemical effects	Secondary physiological effects	Therapeutic uses
Galvanic	Mild thermal; pos. pole: acid reaction; neg. pole: alkaline reaction; iontophoresis; cataphoresis	Vasomotor stimulation	Relief of inflammatory changes; mild caustic effects; introduction of drugs
Low-frequency currents	Mild thermal; alternating acid or alkaline reaction	Sensory and motor nerve stimulation	Exercise of weak and paralyzed muscles
High-frequency	Profound thermal	Increased circulation—sensory and motor nerve sedation; bactericidal	Relief of pain and spasm; promotion of nutrition and absorption
Static wave and spark	Mechanical	Sensory and motor stimulation, molecular tissue massage	Relief of local stasis; exercise of muscles

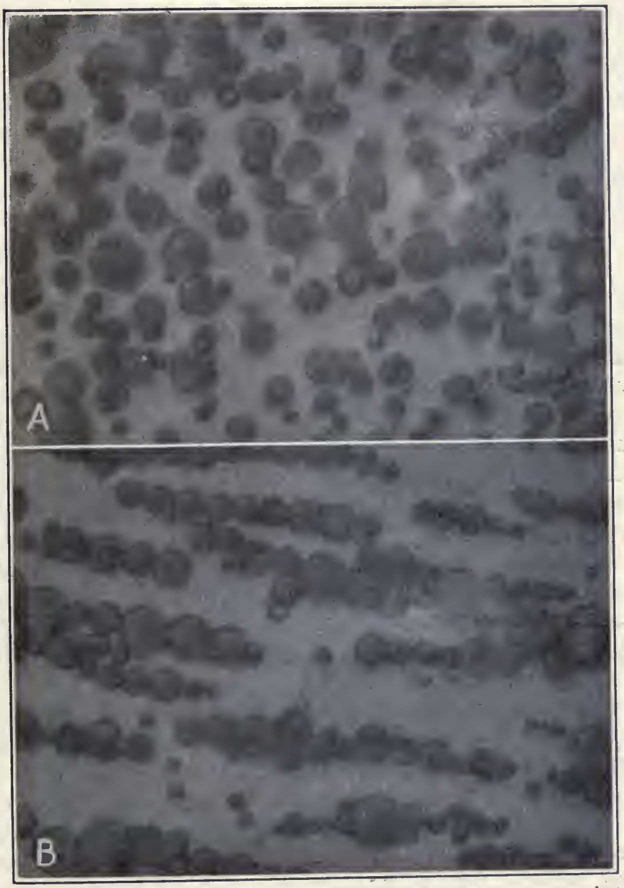

Fig. 56.—Electric effect of ultrahigh-frequency field on fat emulsion. *A*, irregular fat globules before energy is turned on; *B*, typical pearl chain formation after energy is on. (Courtesy of Dr. P. Liebesny.)

Secondary Physiological Effects.—The physiological action of the various electromedical currents depends on the primary physical effects just outlined. They include: (1) action on the vasomotor system, vasomotor stimulation lasting from a few minutes to several hours, with subsequent effects on circulation and nervous reflex effects, (2) action on the neuromuscular system, stimulation or sedation of muscles and nerves, (3) effects on local and general metabolism. These manifold effects are discussed in the special chapters for each current.

Psychological Effects.—It is well known that a certain psychological effect may occur with any form of electrical application, just as it may occur with any other form of treatment, whether by drugs, diet or surgery. The fact that electricity has become a much more commonplace object in daily, commercial and home life has taken away much of the awe formerly existing toward its seemingly mysterious nature and consequently, the more intelligent public of today is less likely to be influenced by an electrical application for merely psychic reasons. In all pathological or functional conditions patients must receive physical treatment on the basis of a definite diagnosis as well based on sound physiological principles. The additional therapeutic help supplied by the unpredictable psychic effect of electricity on any individual is not unwelcome, yet no thoughtful physician will nowadays misinterpret these effects as the main result of electrical treatment. Hysterical paralysis and paresthesias are perhaps the only functional disturbances in which some form of electricity may be indicated for a purely suggestive effect.

ELECTRIC CONDUCTION THROUGH THE BODY

The human body consists of a composite mass of tissues and fluids with varying electric conductivity. According to Hemingway and Stenstrom,[2] the problem of electrical conduction in the tissues is a problem of conduction in an electrolytic solution and a tissue may be regarded as a non-homogeneous solution. In applying an electrical current to the body conduction and subsequent effects will depend (1) on the form, strength and duration of the current, (2) on the structure and area of the application.

Resistance of the Skin.—The factor of skin resistance is of primary importance in electrotherapy. The resistance of the skin being comparatively much greater than that of all other parts may be considered as a measure of resistance of the entire body. Generally speaking, the skin can be considered as a partial conductor, the conductivity of which is increased by mechanical, thermal or chemical stimuli. It is an important organ of protection, perception, absorption and excretion. It varies in thickness in the different regions of the body, from about ½ to 4 millimeters. The topmost of its two principal divisions is the epidermis, consisting of a superficial horny layer, the protecting and insulating coat and a heavy subcutaneous layer; neither of these contain any blood-vessels, but they admit the flow of nutritional fluids from below through little channels. These nutritional channels, and mainly the opening of the ducts of the sweat glands, serve as paths for the entrance of low-tension currents. The lower division of the skin, the corium or true skin, is formed of connective tissue united with elastic, smooth muscle fibers, and it contains an abundance of capillary blood-vessels. (Figs. 211 and 218.)

The relative resistance of the various parts of the skin is determined by their histological difference. The horny layer of the skin offers most of the resistance. Parts habitually exposed offer less resistance on account of the thinness of the skin. The relative porosity or the distribution of the sweat glands influences skin resistance considerably, hence the much better conductivity of the palms of the hands as compared to the backs of hands, in spite of the thicker horny layer. The soles of feet are the most resistant on account of their thick horny layer and the absence of sweat glands. Heat decreases skin resistance by bringing on perspiration due to an increased activity of the sweat glands. In experimental studies subcutaneous injections of pilocarpine well away from the hand increased the conductivity of the palms of the hands.

Skin Resistance to Different Currents.—It is evident that the form and strength of current will have a different influence on the resistance of the skin.

It has been shown that the flow of a direct (galvanic) current creates an opposite electromotive force in the skin under the electrodes, known as *polarization*. This phenomenon can be easily demonstrated any time after the flow of the galvanic current, if one leaves the parts and electrodes in the same position after the rheostat is turned back to zero. It will be seen that the needle of the milliammeter will swing out immediately in the opposite direction for a fraction of time. This indicates an opposite current flow in the patient's circuit. Richter[3] demonstrated that the resistance offered to a direct current of small strength is localized practically in the skin; a minute puncture made through the skin decreased the resistance from any level to zero.

A current of greater strength will have a greater power to overcome skin resistance. Currents of high frequency such as diathermy cause no polarization on account of the very short duration of each impulse. This and their high voltage explains the minimal amount of skin resistance towards them.

Experimental Demonstrations.—The following experimental demonstrations show the difference between the skin resistance to the galvanic current (low voltage) and diathermy (high voltage).

(*a*) *Galvanic Current.*—1. A human subject holds in his dry hands two metal cylinders connected to the terminals of a galvanic generator. Advancing the rheostat far up will result in only a slight excursion of the needle of the meter, about 2 to 3 milliamperes. Turn off current. The subject now wets his hands with salt water and grasps the cylinders again, being careful not to contact them. Turning on the rheostat to the same extent, the needle will swing out much farther.

2. Two pad electrodes are placed in dry condition on two opposite surfaces of the body. Connected to a galvanic source, no matter how strong a current is turned on, there is no sensation underneath the electrodes and the needle of the meter does not indicate the flow of any current.

These experiments demonstrate that the dry skin even with good metallic contact will conduct only a fraction of the galvanic current compared to its moist state, also that dryness of the interposed asbestos pad prevents the passage of any current.

3. The subject holds one cylindrical electrode in each hand. A moderate amount of galvanic current is turned on, then the subject closely approxi-

mates the balls of the hands—without touching the electrodes. In spite of the shorter path offered, directly from hand-to-hand instead of *via* the arms and across the shoulders, no increased current flow is shown by the meter.

This experiment demonstrates that the skin offers so much resistance to the galvanic current that it will take the longer course along the less resistant blood-vessels and muscles, instead of the shorter path necessitating another passage across the skin.

(*b*) *Diathermy.*—1. The subject holds in his dry hands two metal cylinders, each connected to the terminals of a long-wave diathermy machine or a short-wave machine with a circuit for direct conduction heating. Increase current in the patient's circuit to about 300 to 400 milliamperes, then turn off the main switch without setting back the other controls. Let the subject moisten his hands with salt solution and grasp the cylinders again, then turn on the main switch. The meter will not register more flow of current than before.

This experiment demonstrates that the skin offers comparatively little resistance to the high-frequency current. The current passes with equal ease through dry and wet skin. Moistening of electrodes is with diathermy, therefore, as a rule, unnecessary.

2. The subject holds two metal electrodes and about 500 milliamperes of current are turned on. He now suddenly and closely approximates the balls of the hands being careful not to allow the electrodes to touch each other; the milliammeter will show at least double amount of current passing.

This experiment shows that the high-frequency current in contrast to low-voltage currents prefers to pass along the shortest path between the electrodes if the resistance is not unduly high.

The resistance of a healthy normal individual to the direct and the alternating current was found to be from arm to arm 1050 ohms with the direct and only 250 with the alternating current; from arm to leg it was 1600 ohms with the direct and 360 ohms with the alternating current. (Laqueur,[4] *et al.*) Recent investigations with a 60 cycle alternating current applied for "electroshock"[6] showed that when voltages between 50 and 120 are applied and there is good contact and good conduction (electrode jelly is used), the initial ohmic resistance of 2000 drops to a value between 300 and 120 ohms almost immediately after the current is made. The living skin thus behaves like an electrolytic condenser which breaks down when voltages above 50 are applied. This study also shows that the sometimes elaborate measures to measure the resistance of the skin before an electric shock treatment are not necessary.

Table 9 sums up the skin resistance to various currents.

TABLE 9.—SKIN RESISTANCE TO ELECTRICAL CURRENTS

Current	Voltage	Polarization	Skin resistance
Galvanic (direct)	Low	Yes	High
Low-frequency	Low	Some	Moderate
High-frequency	High	None	Little
Static	High	None	Little

Practical Importance of Skin Resistance.—The difference in the skin resistance toward the various currents explains the difference in technique in their application. When applying currents of low tension moist pads are interposed between the plain metal electrodes and the skin to overcome the high skin resistance and to prevent electrolytic changes. Warming up and moistening the skin or the use of electrode jelly helps to decrease resistance and improves conductivity. Practically no conduction occurs when dry metal or dry pad electrodes are placed upon the dry skin, no matter how strong a galvanic current is turned on. The moist gauze or asbestos pad also serves to prevent corrosive effects liable to occur under bare metal when a direct or galvanic current is applied. After the current has flowed for a while conduction improves and the milliammeter indicates a larger amount of current flow.

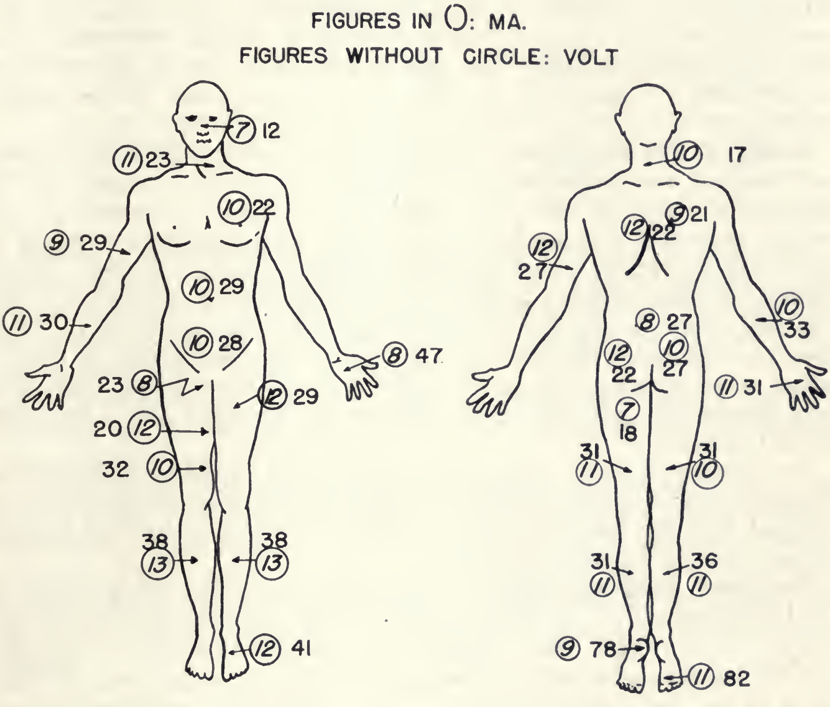

Fig. 57.—Distribution of skin resistance and pain sensitivity to electric current. (Courtesy of the Merck Report.)

In applying currents of high voltage, such as long-wave diathermy or the static-wave current, plain metal electrodes are used. The smooth passage of current is aided by directing the rays of a luminous heat or infrared generator for a few minutes to the area to be treated, and by slight warming of the plates by the same source of heat.

The size of the electrodes and the distance between them plays an important rôle in skin conductivity. It is evident that the larger size of the electrodes offers larger surface for the entry of the current. This result is a decrease of skin resistance proportional to the area of application. When electrical currents are applied in a full water bath very large amounts of current can be introduced.

Gentle pressure upon moist electrodes decreases skin resistance by better contact and by producing greater saturation with moisture. Too much or uneven pressure may lead to burns through relative ischemia of the skin or through excessive current density.

The distribution of skin resistance and pain sensitivity to the galvanic current over various points of the skin was recently investigated by Molitor[7] by applying galvanic currents of increasing strength and recording the milliamperes and volts when the subject felt that the tolerable limit has been reached. While sensitivity to pain and skin resistance varied considerably in various individuals, the general trend was unmistakable. It showed that (1) at the point of maximum tolerable current the voltage readings vary greatly at various points of the body surface, depending upon skin resistance at the site of electrode application. (Fig. 57.) (2) The maximum tolerable current density depends to a large extent upon the size of the electrode, being relatively greater with a small electrode and smaller with the large one. (3) The total current which can be applied without producing pain is far greater with a large electrode.

Changes in Skin Resistance.—Observations in a large number of subjects, both normal and psychopathic, by Richter[9] have shown that: (1) All agents that stimulate the skin produce a decrease of resistance; (2) the palmar resistance is dependent on the sweat glands and is controlled by nerve impulses arriving through the sympathetic nervous system; (3) the palmar resistance shows a large increase during sleep, following nerve section and severe shock, and just preceding and following death (in all of these conditions the impulses reaching the skin are diminished or there is actual interruption of the nerve pathways); (4) high palmar resistance over a prolonged period of time is liable to be associated with a depressed mental condition.

An increase of skin resistance is usually found according to Richter in hysteria, myxedema, in old age and cachectic conditions, as well as in cerebral infantile paralysis, while a decrease is found in hyperthyroid subjects and in traumatic neurosis.

Resistance of Other Tissues.—*Electrical conductivity* of all tissues of the body depends (1) on their content of water and (2) on their relative density. The relative conductivity of the various tissues is about equal to their content of water, this being approximately as follows: Muscle, 72 to 75 per cent; brain, 68 per cent; fat, 14 per cent; peripheral nerves, skin and bone, 5 to 16 per cent. In general, tissues that contain the most water, and are, therefore, richest in ions, are the best conductors.

Muscle and brain show the best conductivity of all the tissues; muscle conducts about four times better in the longitudinal direction of its fibers than transversely. Tendons and fasciæ are poor conductors on account of their lesser content of water and their density. The location of the brain and spinal cord in poor-conducting bony tissue does not modify their electrical conductivity to a great extent. It has been proved that effective amounts of current pass through the cranium as well as through the spinal column. Peripheral nerves conduct six times as readily as muscular substance; it is difficult to utilize this advantage, however, because a nerve is usually surrounded by fat and by a fibrous sheath, both being poor conductors. The subcutaneous tissue is a relatively good conductor. Bones are the poorest conductors, especially those of dense structure.

Internal organs, such as the liver, lungs, stomach and intestines, offer a varying degree of resistance, dependent on their relative content of blood, air, connective tissue and, in the case of the hollow viscera, their contents.

A study of Bachem[1] on the resistance of the dead organs of the human body corroborates the above findings and demonstrates as well that the resistance depends on the variety of current. It is smallest for high-frequency, medium for low-frequency and greatest toward direct current.

TABLE 10.—SPECIFIC RESISTANCE OF HUMAN ORGANS (BACHEM)

	Current		
	High frequency, Ohms	Alternating, Ohms	Direct, Ohms
Liver	230	1,600	8,000
Spleen	230	2,100	7,700
Muscle	255	1,500	9,000
Skin:			
Dry	435	300,000	4,000,000
Wet	435	250,000	380,000
Fat	2,700	3,250	108,000
Lungs:			
Collapsed	485	1,820	5,400
Bone (tibia)	12,300	15,400	22,500
Kidney	200	1,400	8,500
Brain	630	2,170	10,700

Dielectric Conductivity.—Experimental and clinical work with electric energy of very high frequency, known as short-wave diathermy, have shown that this form of energy can pass through electrically non-conductive substances because dielectric permeability or conductivity increases with the increase *of the frequency of currents.*

The flow of an electric force through the insulating or dielectric medium is known as a "capacitative" current in contrast to the "conduction" current through an ordinary electric circuit.

All substances whether conductors or non-conductors possess the property of dielectric permeability under an electrical charge. This is expressed numerically in the form of the dielectric constants of substances. The unit of dielectric permeability is that of air under normal pressure; body tissues and liquids transmit the electric field force from 80 to 90 times better than air space. Table 11 presents the dielectric constants of the various substances.

TABLE 11.—DIELECTRIC CONSTANTS OF VARIOUS SUBSTANCES

Air	1
Glass	4–10
Mica	5– 6
Wood	3–10
Water	80
Body tissues and liquids	80–90

Dielectric substances may be considered in their smallest particles as electric dipoles, that is, small particles possessing a positive charge at one end and a negative charge on the other. It is assumed that in a sufficiently powerful electric field, changing its direction a few million times a second, these dipoles tend to line up in the same manner as the unit magnets in a magnetic field (Fig. 58); at each change in the electric field they twist back and forth and the friction of neighboring particles creates considerable heat.

It has been asserted that because of the dielectric property of some of the ordinarily poorly conductive tissues very high-frequency currents can be effective in regions which would otherwise be more or less inaccessible to a purely conductive current. Hence inner organs, the spinal cord and the brain, all of which are closed off by poor conductors (fat, bones, etc.) may be heated without overheating the tissues around them. It is the generally accepted view that short-wave diathermy passes through the tissues of the human body partly as a current of conduction and partly as a "current of capacity" as indicated in Figure 55. However, in actual clinical practice there is little if any difference in the effectiveness between long-wave and short-wave diathermy.

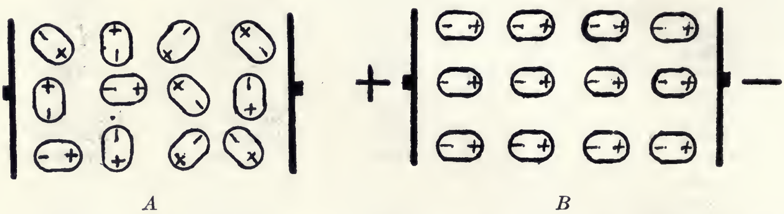

FIG. 58.—Schematic illustration of effect of a condenser field on molecular dipoles. *A* shows the molecules arranged in no particular order with no electric field applied; *B* shows their alignment under the influence of an electric field with the negative poles toward the positive plate pole and the positive pole towards the negative pole. The rapid change of the charger of the condensers will in the next instant tend to reverse the direction of these dipoles. This molecular friction exercises a heating effect on the molecules in the electric field irrespective of their electric conductivity.

THE PASSAGE OF CURRENTS THROUGH THE BODY

Current Density.—After having overcome the resistance of the skin and having entered the body, an electrical current usually flows in a direct line from one electrode to another, as shown by the recent experimental studies of Weeks, Alexander and Dennis.[11] Only those tissues show response which lie in its direct path. It is evident that the area immediately underneath the electrodes will show most of this response.

The most important factor in the action of a current on a given area is the *density* of the current. A given amount of current passing through a large area may exert no appreciable effect, but when concentrated in a conductor of small diameter, as, for instance, in the skin under a small electrode, it may produce a very marked effect, amounting even to destruction of tissue. The *density*, and hence the physiological effect, of a current is directly proportional to the square of its strength and inversely proportional to the cross-section of the area through which it flows. There is no known measure of density; the amount of milliamperes flowing through an electrode does not furnish a measure of density, but if the size of this electrode is known then the number of milliamperes per square inch will give an accurate measure of the density underneath. The density of a current may be increased (1) by decreasing the size of the electrode or (2) by increasing the amount of current. There exists a marked limit of physiological tolerance of tissues, especially of the skin, to the density of current.

Under physiological conditions the comfortable toleration of the patient is the principal guide of safe current density. It is estimated that each square inch of normal skin can comfortably tolerate about 1 to 2 milliamperes of the direct current, a slightly larger volume of a low-frequency current, and about 75 to 100 milliamperes of the high-frequency current. This considerable difference in the volume of current tolerated explains

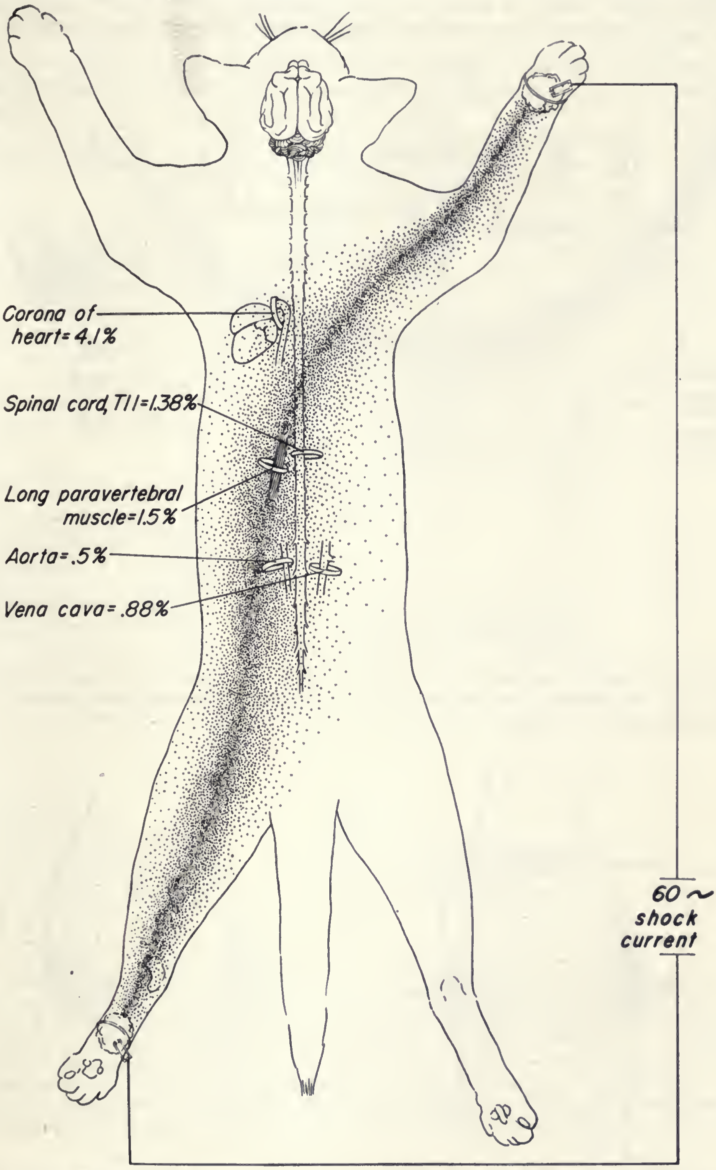

Fig. 59.—Observation of distribution of 60 cycle alternating current in various parts of the body of the cat. Passage of current from forefoot to hindfoot, amounts carried by the aorta, vena cava, spinal cord and long muscles of the back were similar. (Weeks, Alexander and Dennis, courtesy of Jour. Indust. Hyg. and Toxicol.)

the profound thermal effects of the high-frequency current. The mucous membranes, on account of the absence of an insulating horny layer and their great vascularity, tolerate more density and allow the passage of a relatively greater volume of current.

It is evident that by increasing the size of electrodes, larger amounts of current can be passed without the danger of burn, but even if the relative density of the current is thus made much smaller, there is a limit of com-

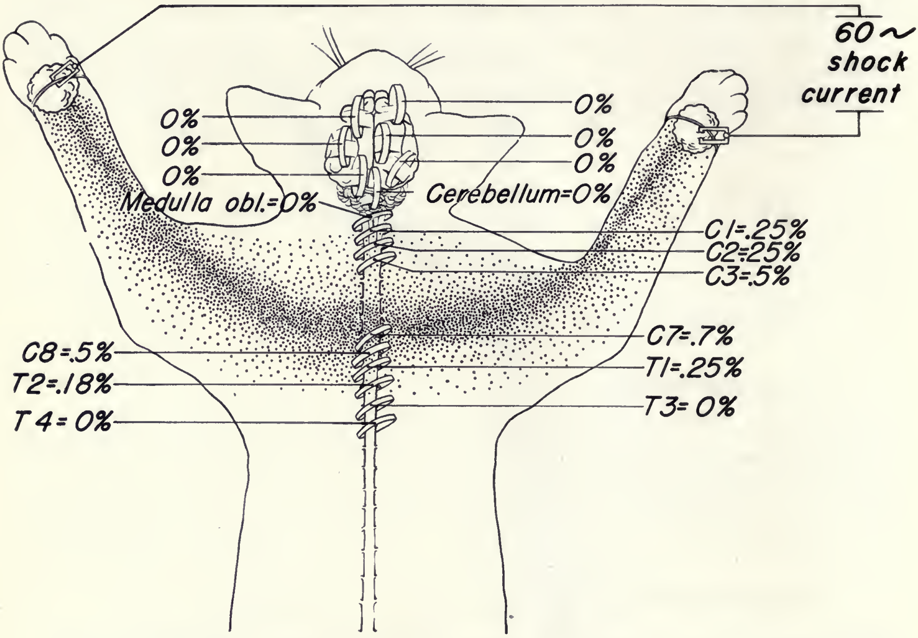

Fig. 60.—Passage of current from forefoot to forefoot. Note current in spinal cord most dense at *C7*, diminishing cranial and caudad. Absence of measurable current in brain. (Weeks, Alexander and Dennis, courtesy of Jour. Indust. Hyg. and Toxicol.)

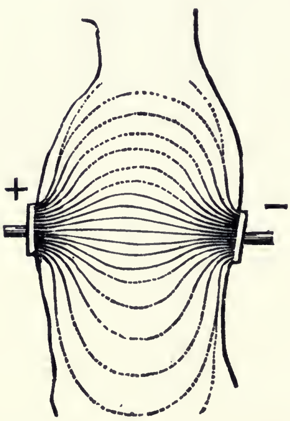

Fig. 61

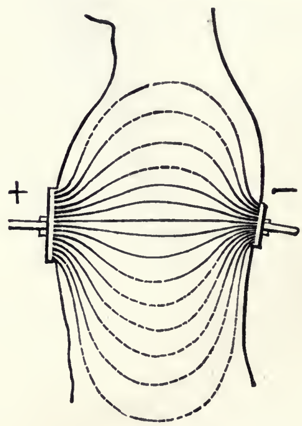

Fig. 62

Fig. 61.—Current distribution with electrodes of equal size. Current density equal under each electrode. (Erb.)

Fig. 62.—Current distribution with electrodes of unequal size. Current density twice as great under the electrode which is one-half the size of the opposite one. (Erb.)

fortable toleration, determined by the reaction of the sensory nerve endings of the skin to the total area of application. A smaller electrode does not insure the passage of a greater relative amount of current as each skin unit will tolerate only a certain density.

Influence of the Size and Position of Electrodes.—Employing two electrodes of equal size, the density beneath each of them is equal; while using one twice as large as the other, the density of the current under the smaller will be four times as great as under the larger. As the current spreads across the body its density must gradually, according to the inverse square

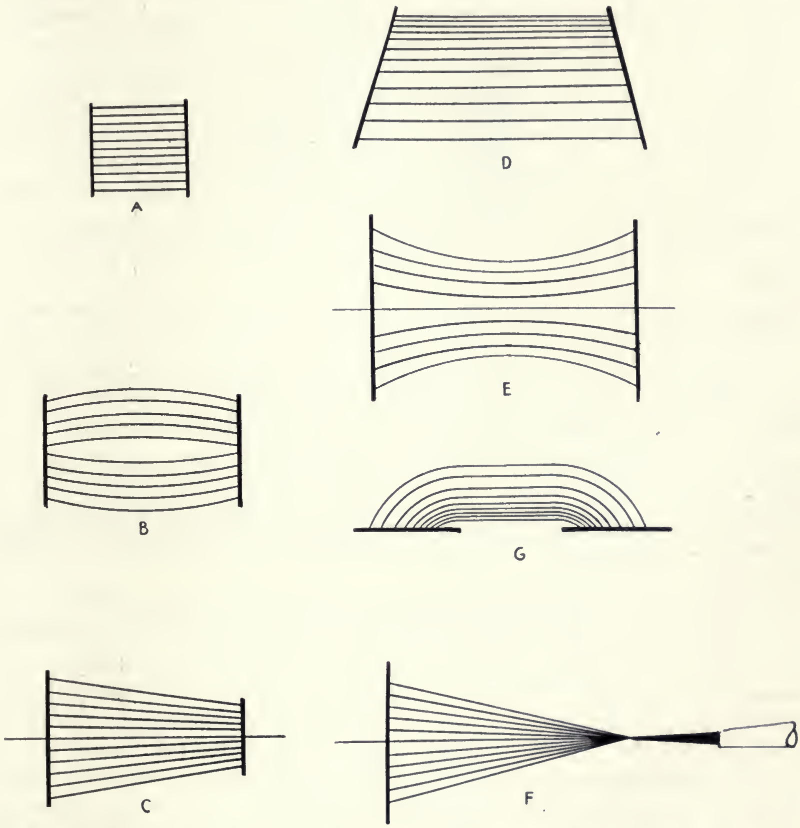

Fig 63.—Various modes of current distribution in homogeneous medium. *A*, Electrodes of equal size, equidistant and relatively close to each other; current density equal all the way through. *B*, Electrodes of equal size, equidistant and relatively far apart; current density less in center. *C*, Electrodes of unequal size equidistant. (See also Fig. 62.) *D*, Electrodes of equal size, slightly tilted toward each other; beginning edge effects. *E*, Path of current narrowing between electrodes; greatest current density in center. *G*, Electrodes on same surface of body; typical edge effect between proximal edges. *F*, Needle point active electrode and large dispersive electrode; excessive current density causing coagulation under the needle point.

law of energy, decrease so that midway between the electrodes the density is usually less. The nearer the electrodes are applied to each other, the greater will be the density of the current between them. If both electrodes are placed on the same side of the body or of an extremity, the density of the current will be the greatest in the skin and in the superficial parts. The closer they are placed, the greater is the density on the surface, with a resulting "edge" effect; this is first manifested by an unpleasant burning sensation and, when unheeded, may result in a superficial blister or deep burn. Edge effects are noted only between the near edges of electrodes and none on their far side.

The influence of the position and relative size of electrodes upon the passage of a current of adequate strength through homogeneous tissue is illustrated in Figure 63.

Placing electrodes of equal size exactly opposite and parallel is designated as *transverse application;* it results in equal current density all the way through, provided that the electrodes are not too far apart. Increasing the distance between the electrodes decreases the current density between them, due to the inevitable dispersion of current in the central area between the electrodes (Figs. 61, 62 and 63 *B*), accordingly one must use proportionately larger electrodes in order to obtain a fairly equal density all the way through. When treating inner organs, Kowarschik demonstrated by a series of experiments with diathermy that as long as the distance between the electrodes is not more than one and a half times their longest cross-section, the density, and thus the heat effect, will be equal all the way through.

Placing electrodes of unequal size exactly opposite to each other results in proportionately greater density under the small area. (Fig. 63 *C.*) The decrease of the size of one electrode simply limits the principal effect of the current to the area under this "active" electrode. This may be desirable when the action of the current is to be restricted, mainly under the area of one electrode (diathermy to frontal sinus, spinal column, prostate, etc., or in muscle and nerve testing). In surgical applications the current density under the active electrode, a needle point or knife, is increased far beyond physiological toleration, and thus leads to tissue destruction. (Fig. 63 *F.*)

When electrodes are tilted toward each other as in Figure 63 *D* the greater part of the current will take the shorter path and thus the density will be greater when the edges approximate each other. Diathermy, for instance, can be concentrated into the subdeltoid bursa by applying two electrodes on each side of the arm and tilting them toward the middle of the deltoid muscle. In the routine transverse application, however, the placing of electrodes in any other than in parallel planes is to be avoided.

If the cross-section of the area between the electrodes is narrower, as in Figure 63 *E* there results a greater density of current in the area of the smaller cross-section than in that under each electrode. This occurs in treating the wrist or the ankle with cuff or plate electrodes applied above and below.

When electrodes are placed on the same plane (Fig. 63 *G*) whether with low-frequency or long-wave diathermy currents the passage of current will be almost entirely limited to the surface area between the proximal edges. When two electrodes are placed on the same plane but some distance apart, the technique of application is designated as *longitudinal* or *co-plane application.* It is estimated that in order to get deeper effects the distance between these electrodes must be not less than 10 inches. If these electrodes are placed circularly around a limb, this is known as the *cuff method.* If these cuffs are quite close the current density will be greatest along the surface, and the bulk of the current completes its circuit by traveling along the skin from electrode to electrode all the way around the limb. If the cuffs are placed far enough apart, however, there will be a certain degree of deeper penetration. Treatment by the longitudinal method (cuffs and semi-cuffs) is the method of choice in the treatment of pathological changes located in the superficial soft tissues, skin, muscles and nerves.

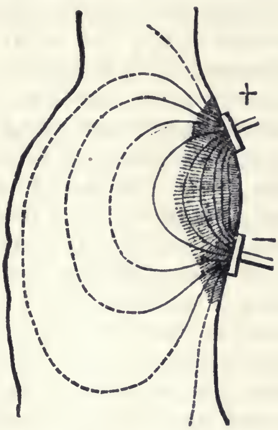

Fig. 64.—Schematic representation of edge effect. Electrodes are applied on the same surface, close by. Zone of greatest density is shaded. (Erb.)

In the inductance cable technique by short-wave diathermy, a cable loop or pancake coil placed on one plane of the body causes so-called "eddy current" effects in the underlying tissues and brings about heating by the circulation of a current in the conductive soft parts.

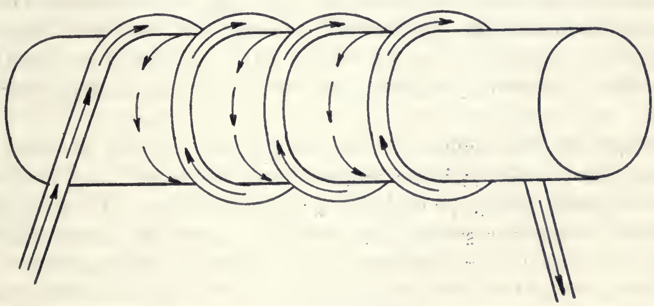

Fig. 65.—Diagram of eddy current (electromagnetic field) effect of short-wave diathermy applied with inductance cable wound around an extremity or the trunk.

GENERAL RULES OF ELECTRICAL TREATMENT

In order to employ electrotherapy safely and efficiently the rigid observation of certain general rules of technique is essential. These rules are herewith given, while additional special rules for each of the currents are presented in the respective chapter for each.

1. **Method of Procedure.**—Calm and business-like method of procedure is essential. Many patients are apprehensive when receiving electrical

treatment for the first time and a nervous, fidgety operator adds to their uneasiness. Patients should be told that electrical treatments do not hurt and do not burn and that there is never more current administered than can be comfortably tolerated. Before patients are brought near an apparatus, the operator must know that it is properly connected up, in good working order and all controls are off or in zero position.

2. **Position of Patient.**—Patients should be placed in a position in which they will remain comfortable during the entire treatment period. For treatment of the head, abdomen, pelvis and thigh or entire lower extremity, patients are best put in a recumbent position. The shoulder and upper arm should usually be treated with the arm propped up (as much abducted as possible) by pillows on a small table; the elbow and forearm should be treated resting on a table. In neck or chest treatments patients may sit propped up in an armchair. For knee, leg or foot treatments an armchair with a foot-part which can be raised is convenient.

3. **Inspection of Parts.**—Before applying electrodes inspect carefully parts to be treated to make sure that the skin over these looks and feels normal. Special precautions in treatment are necessary in case of recent scar tissue, in peripheral nerve injuries and other cases of disturbed sensation. Preliminary exposure for ten minutes to luminous heat is a good routine measure to warm and relax the parts and decrease skin resistance.

4. **Placing of Electrodes and Cords.**—Choose electrodes of proper type and size, warm diathermy plates under a heat lamp or moisten galvanic pad electrodes with warm salt solution. Place electrodes in correct position and see that they are in good contact all the way through. Secure electrodes by elastic bandages (avoid too much and too tight bandaging) or small sandbags; whenever possible hold one electrode by part of the body resting on it. Fasten conducting cords to the electrodes and binding posts (terminals) of the apparatus, hold condenser pads by bandaging and insert their cable connection into the terminals of the apparatus. See that electrodes and conducting cords stay secure during entire treatment. Avoid crossing of short-wave diathermy cables and the touching of any metal surface by them.

5. **Starting the Treatment.**—Everything is now ready to start the flow of current. Set the time clock or automatic switch for the prescribed time. Turn on the main switch to admit the supply current. Proceed to turn on a comfortable current strength by gradually opening the controls. Warn the patient to report any unpleasant sensation—pricking, excess heat—at once. *Never leave the patient out of sight or sound once the treatment has been started,* unless there is an arrangement whereby if necessary the patient can instantly shut off the current and knows how to use it.

6. **Regulation of Current Strength.**—It should take three to five minutes to reach the maximum current strength and to allow for gradual overcoming of skin resistance, avoiding stimulation of sensory reflexes. The strength of current to be employed depends on the size of the active electrode, the condition to be treated and the individual sensitivity of the patient. If the patient complains any time during treatment about pain, burning or any other unpleasant sensation and decreasing the current strength does not give immediate relief, turn off current entirely. After patient is comfortable again advance controls carefully; if patient still

complains, take off and inspect electrodes and their site, making sure that all controls are off. There may be poor contact or too much pressure under the electrodes, or the patient may be simply oversensitive. After reapplying electrodes proceed as on first starting current; never push up current strength if the patient is not entirely comfortable. It is generally more beneficial to use a moderate amount of current for a longer period than to push up the current to the full limit of toleration for a short intensive treatment.

In judging sensitivity of patients, their temperaments as well as the location of electrodes must be taken into consideration. Patients of the sensitive, nervous type usually stand less current at the beginning. On the other hand there are patients who are not satisfied unless they get the maximum current they can stand. There are ignorant types like the patient who does not believe that the medicine can be active unless it has a nasty taste, who think that an electrical current must burn and consequently fail to report burning sensations at their inception; as a result some of these patients may develop burns. In nervous children, in order to get them used to the situation, it may be advisable at the first sitting to apply the electrodes without turning on the current.

Different areas of the skin are of different sensitivity, it is well known that the skin of the forehead, the hands and feet tolerates heat better than other parts. In nerve injuries and other disturbances of peripheral sensitivity special precautions have to be taken as will be pointed out later.

7. **Termination of Treatment.**—Turn off controls slowly in the reverse order to that in which they were turned on. Take off electrodes only after the current has been turned off entirely. See that all controls are turned back to zero. Inspect the site of electrodes; nurses must report any unusual changes at once to the physician in charge and make a record of them. Let patients rest for a few moments after every treatment. In inclement weather make sure that patients are allowed ten to fifteen minutes to cool off before they go outside.

Observing these simple precautions will greatly help to avoid embarrassing moments at the beginning of one's electrotherapeutic practice. Accidents resulting in burns or other mishaps may occur unavoidably from time to time, but as long as the physician has used a method and technique accepted as standard, and the accident is not the result of any neglect or improper act, he will be relieved from all unreasonable responsibility. Accidental injuries are discussed in detail in Chapter XIV.

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CHAPTER VI

ELECTROPHYSIOLOGY

Bioelectric Phenomena. Action Currents in Skeletal Muscles. Action Currents in Nerves. Injury Current. Action Currents of the Heart and Brain. Theory of Bioelectric Phenomena. Electrical Stimulation of Muscles and Nerves. Nature of Nerve Impulses. Stimulation by Direct Current. Electrotonus. Nerve Block. Electrical Excitability. Strength—Duration Curves. Chronaxie. Progressive Currents. Intensity—Frequency Relation.

Bioelectric Phenomena.—In recent years far reaching discoveries were made about the production of electrical potentials in the living tissues. It seems evident that changes of ionic concentration are constant by-products or factors in all living processes. This newer knowledge allows not only a better understanding of the principles of electrodiagnosis, but also enables some interpretation of the possible effects of electromedical currents on the structures of the body especially in low-frequency stimulation of muscles. Hence it seems appropriate that as an introduction to the physiological basis of electrodiagnosis presentation be made of some of the bioelectric phenomena connected with vital processes.

ACTION CURRENTS

Electrical currents arising within the body in connection with cellular activity have been demonstrated in all living tissues, such as nerves, the central nervous system, glands, retina, etc. Starling[5] states: "Every beat of the heart, every twitch of a muscle, every stage of secretion of a gland is associated in some way with electrical changes." Burr and Lance[1] state: "Electrical differences are constant but vary from moment to moment and presumably, therefore, must be intimately related to such things as cell division rates, metabolic rates, the internal economy of each cell, etc."

The momentary difference in electric potential between active and resting parts of a nerve fiber or muscle is known as the *action current*. It can be demonstrated by connecting the two parts with a sensitive galvanometer. To record these potentials it is necessary to employ non-polarized electrodes, in which the metallic electrode is dipped into a solution containing its own ions such as zinc, copper or silver; this solution is separated from the sodium chloride solution of the tissues by a porous material such as kaolin. Such an arrangement prevents a "polarization" current from the liberated hydrogen and dissolved metal in ordinary electrodes, which complicates the depolarization phenomena associated with excitation (page 83).

Action Currents of Skeletal Muscles.—In the human body it is possible to record the action potentials resulting from voluntary muscular contraction. If coaxial needle electrodes are inserted into the muscle the activity of a single motor unit is recorded. Surface electrodes are used to record from the whole muscle. The single action potential is a diphasic wave of short duration in the range of one millisecond with the characteristics of a spike. At rest under conditions of complete relaxation there are no currents recorded with standard techniques. During gentle muscular contractions the motor units discharge in a range between 6 and 60 per cent, the amplitude and frequency increasing with the strength of contraction. (Fig. 66.) The individual motor units discharge independently and asynchronously. The entire muscle discharges at a higher frequency about 300 per second during a muscle tetanus.

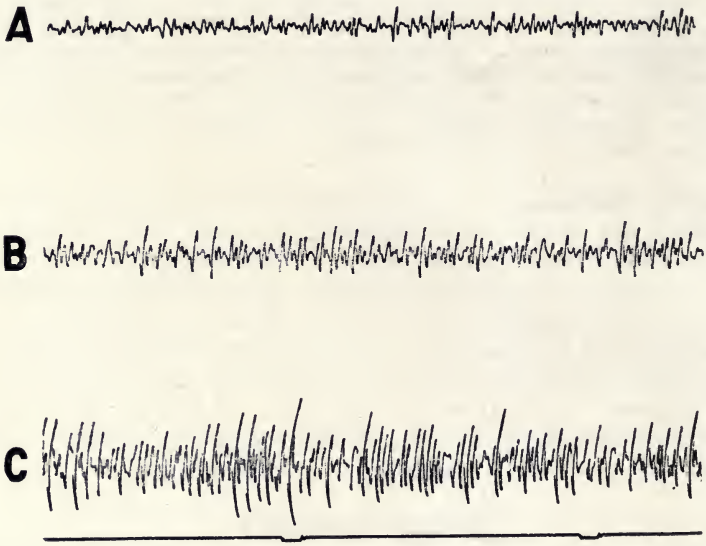

FIG. 66.—Normal muscle. Electromyogram of gentle (*A*), moderate (*B*) and strong (*C*) contraction. Time interval one second on bottom signal. (Electromyographic Laboratory, Massachusetts General Hospital.)

In recent years apparatus has been developed which can be used in the clinical study of a number of diseases affecting the lower motor neuron. The electromyographic findings in poliomyelitis, progressive muscular atrophy, Parkinson's disease and peripheral nerve injuries will be discussed in a later section.

Action Currents in Nerves.—With the use of the newer methods of investigation, notably the cathode ray oscillograph and vacuum tube amplifier, action currents of nerves have been studied and conduction along individual nerve fibers, rather than whole nerves investigated, for it has been found that different types of nerve fibers have different rates of conduction. It has been known for some time to physiologists that the excitement of a nerve is followed by certain definite periods of excitability. On stimulation, a physicochemical change takes place in the nerve for a very short interval of time, during which no further excitement is possible. This period is known as the *absolute refractory period* and lasts about 1 σ (1 sigma is 1/1000 of a second). Following this is a variable period up to 15 σ in length during which the nerve recovers its conductivity, first rather rapidly and then more gradually. This is the *relative refractory period.* This period is often followed by the supernormal period during which the nerve is most excitable. The highest frequency of stimulation to which a nerve is able to respond depends upon the length of its refractory period. Thus, an absolute refractory period of 1 σ limits the rate stimulation to 1000 impulses per second. Some of the larger myelinated axons respond to a current of 2000 impulses per second, hence must have an absolute refractory period of about 0.5 σ. The maximum frequencies noted in nerves carrying natural impulses was about 400 per second. This gives a rather large factor of tolerance for the rate of the stimulating current.

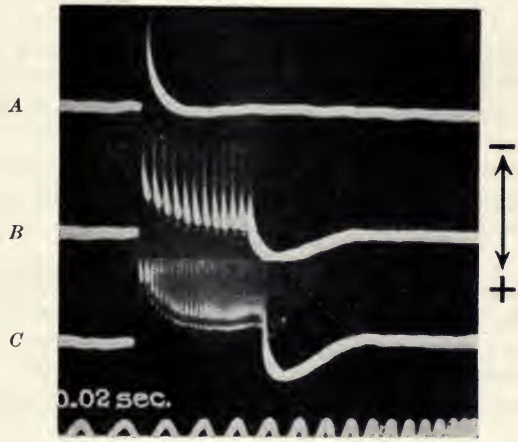

FIG. 67.—Cathode-ray recorded by action potentials in a phrenic nerve. *A*, upper curve, single shock; *B*, brief tetanus at 180 per second; *C*, brief tetanus at 350 per second. Temperature 37° C. Note development of positive after-potential. (Gasser, Harvey Lectures, courtesy of Williams & Wilkins Company.)

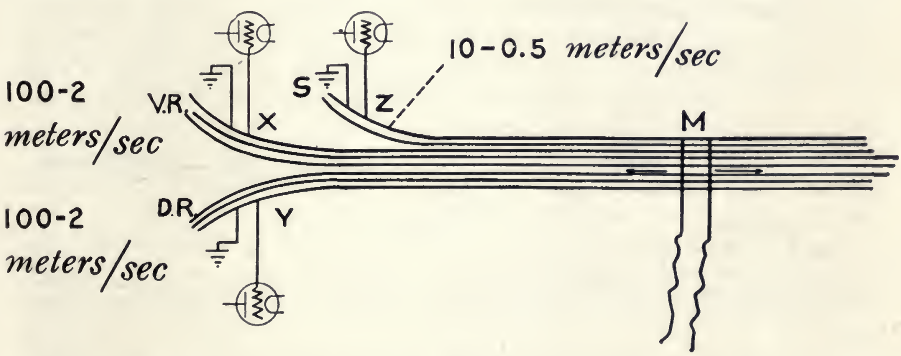

FIG. 68.—Diagram illustrating method of determining components in branches of a mixed nerve. *DR*, dorsal root; *VR*, ventral root; *S*, sympathetic component; *X*, *Y*, *Z*, leads to amplifying oscillograph; *M*, point of stimulation of whole nerve. (Wiggers.)

All somatic nerves are large bundles of mixed fibers of varying kinds. The sciatic nerve of a frog, for example, contains about 4000 myelinated and about 8000 unmyelinated fibers. Each type of fiber has a specific conduction rate. Cathode ray studies have shown three types of waves, A, B, and C. A waves travel along a nerve bundle at the rate of 30 to 90 meters per second, B waves at the rate of 15 to 25 meters per second and C waves at the rate of 1 to 2 meters per second. Motor fibers are known to have predominantly the A type of conduction. Sensory fibers at the dorsal root show a mixture of all three types of conduction while the sympathetic gray rami show types B and C.

Injury Current.—Another bioelectrical phenomenon in muscles and nerves is known as the injury current. If there is local injury to the human tissues and one non-polarized electrode is applied to the damaged region while the other remains in contact with the uninjured part, a current will flow towards the damaged region, as shown in Figure 69.

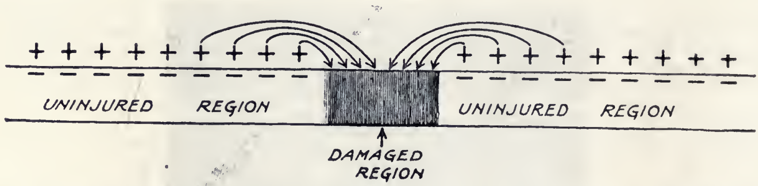

Fig. 69.—Scheme of injury current. Current flow from uninjured to damaged region. (Winton and Bayliss' Human Physiology, courtesy of J. and A. Churchill.)

The explanation of the injury current according to Winton and Bayliss[8] is that the injury ruptures a structure in the tissues, presumably a membrane of varying permeability which ordinarily prevents the passsage of a polarization current. As a result ions, normally kept apart, are allowed to pass in and out through the membrane. The direction of the current shows

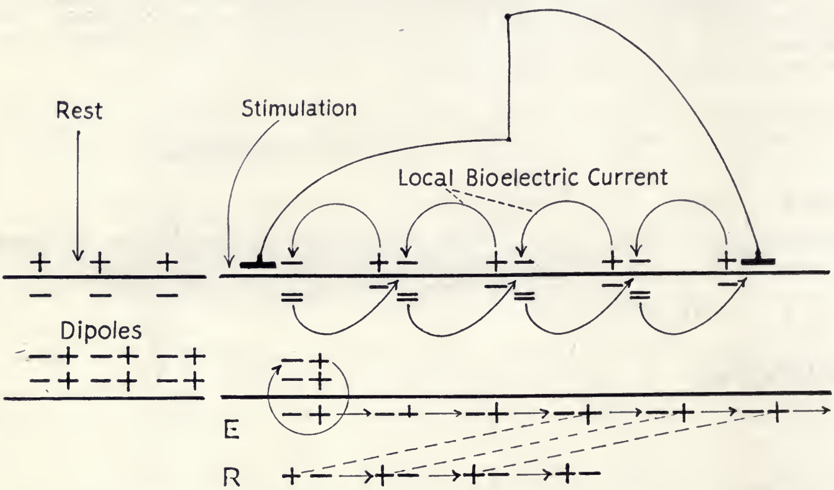

Fig. 70.—Scheme showing (above) local bioelectric currents and spread of impulse according to theory of transverse depolarization, and (below) spread of excitation according to the theory of longitudinal polarization. *E*, excitation; *R*, recovery. (Wiggers.)

that negative ions pass out and positive ions pass in. It is evident that since tissues are not electrically charged, they cannot contain a store of negative ions without also containing a store of a corresponding number of positive ions. If these positive ions were also inside the membrane, they would neutralize the negative ions and there would be no such thing as an injury current. This leads to the conclusion that the positive ions must be outside the membrane, and the negative ions inside, as shown in Figure 69, there must be, therefore, a state of permanent polarization in resting nerve and muscle.

Action Currents of the Heart and the Brain.—It was known since 1856 that the contraction of the heart was associated with a change of electric potential and in 1903 Einthoven invented the delicate string electrocardiograph with a camera to photograph its deflections. *Electrocardiography* has since that time assumed a major rôle in the diagnosis of heart conditions.

In recent years it was recognized that all functional activities of the cortex of the brain are associated with electric changes and gradually *electroencephalography* has begun to play an increasingly important rôle in the understanding of the function of the brain and in the diagnosis of the disorders of the central nervous system.

Theory of Bioelectric Phenomena.—The electrical potential differences following excitation may be explained either by movement of ions across polarized membranes or by a sudden fall of potential across the membrane.

The local bioelectric current so developed is believed to affect adjacent regions of the membrane causing a serial depolarization or potential drop and a spread of the impulse, as shown in Figure 70.

ELECTRICAL STIMULATION OF NERVES AND MUSCLES

Nature of Nerve Impulses.—A stimulus or excitant according to Wiggers[7] represents biologically a change in environment either naturally or artificially induced. In the body these generally consist of chemical or physical influences which produce polarity changes at membrane interfaces with sufficient rapidity to stimulate a cell to action. Electrical stimuli when properly used and controlled most nearly approximate natural physiological impulses. The effectiveness of an electrical stimulus depends on its intensity, its form and on the duration of its effective period.

When a nerve is excited naturally or artificially by a stimulus, *i. e.*, by a sudden change in its environment, a local disturbance is set up which is propagated in both directions from the point of stimulation. This is variously designated as the nerve impulse, the excitation wave or the propagated disturbance. It differs fundamentally from physical waves or mechanical oscillations, (*a*) in that the energy for progression is not derived from the energy of the stimulus but from successive physical and chemical changes in the fiber over which it travels and (*b*) in that it is conducted without loss of intensity, *i. e.*, without decrement. The velocity of impulse conduction in motor nerves in general has been found to be 70 to 100 meters per second in mammals.

The independent irritability of muscles was first demonstrated by the classical experiment of Claude Bernard, who injected an infusion of curare into the dorsal lymph sac of a frog. The animal became paralyzed and the stimulation of motor nerves by single electrical impulses caused no contraction, while direct stimulation of the muscle evoked a normal response. The prevalent opinion is that in normal muscles an electrical current stimulates muscle cells directly as well as excites twigs of nerve fibers in the muscular mass.

All forms of voluntary *muscular contraction are of tetanic nature.* Wiggers states that stimuli originate in the pyramidal cells of the cerebral cortex, are propagated by a long axon down the spinal cord and pass over synaptic junctions with the dendrites of spinal cord cells. In this way the excitation process, initiated in the central neuron, excites the cell bodies of the peripheral neurons. From the spinal motor neurons impulses are transmitted to the muscle fibers by axons leaving the spinal cord. It is well known that such voluntary contractions are not twitches nor jerks such as have been discussed; on the contrary, they are smooth, graded, sustained and larger contractions which result in graceful movements of the bony levers to which they are attached. Such contractions are due to the fact that the pyramidal cells send out not a single stimulus, but successive volleys of impulses which are graded as to frequency and duration. According to Piper they enter the muscle at a rate of 42 to 100 per second.

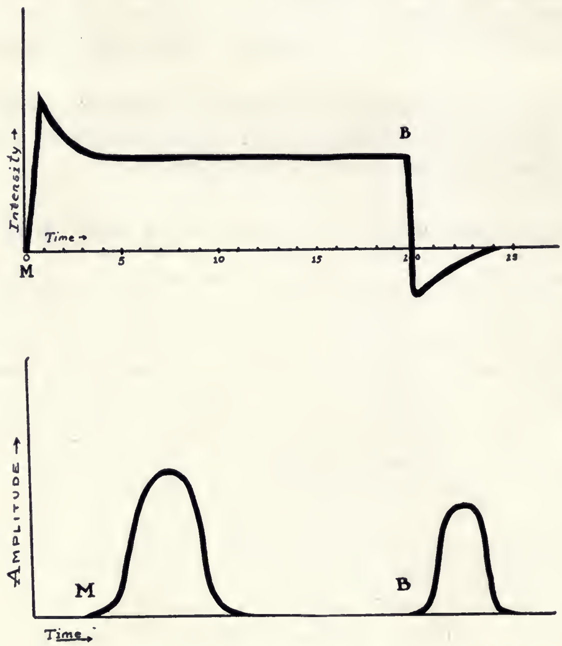

FIG. 71.—Response of normal muscle to stimulation by direct or galvanic current. *M*, make; *B*, break. Response occurs only at peaks between 0 to 3 and 20 to 23 and is less strong on break than on make. (After Cowan.)

Stimulation by Direct Current.—If a galvanic (direct) current is suddenly started or interrupted ("made" or "broken") over muscular parts or motor nerves, there occurs a muscular contraction or phenomenon of a sensory character (slight shock), at first under the electrode connected to the negative pole and with a suitable increase of current strength also under the electrode connected to the positive pole.

The law of electrical muscle and nerve stimulation as first formulated by DuBois-Reymond[2] states that the intensity of a stimulus and the subsequent muscular contraction are directly proportional to the magnitude and change in current strength (voltage and amperage) or, in the presence of same current strength, the intensity is proportional to the rate of fluctuation (the rapidity with which it occurs). Nernst[3] first promulgated the theory that stimulation of muscles and nerves was due to changes in ionic concentration at the cell membrane: ions migrate at different velocity through the two media of the body in which they are soluble: the interstitial tissue fluid and the protoplasma of the cells themselves. At the border zone of these fluids, changes in ionic concentration occur in accordance with the strength of the current and its duration. These differences in concentration act as stimuli until they are equalized by a process of diffusion. The steadily flowing galvanic current causes no muscular contraction because there is not enough change in its strength or its rate of fluctuation to act as a stimulus. Turrell[6] and others state that the relatively high velocity of the hydrogen ion is primarily responsible for the stimulation of muscle and nerve tissues at the make-and-break of the galvanic current. The velocity of the hydrogen ion is so high compared with other ions that when we abruptly make or increase in strength a direct current flowing through the body, the hydrogen ions of the tissues traversed by the current momentarily concentrate in excess of the normal equilibrium at the negative pole and cause a muscular contraction or phenomena of a sensory character in the neighborhood of the negative pole.

When we break or abruptly decrease in strength an electric current passing through the body, the hydrogen ions have been traveling with such relatively high velocity from the positive pole that a temporary deficiency of them exists in that region, leading to a hydroxyl ion or alkaline concentration. This, in turn, excites a contraction in the neighborhood of the positive pole.

Electrotonus.—The closing ("make") of a direct current on a nerve produces an increase of irritability at the negative pole or cathode (*catelectrotonus*) and a decrease of irritability at the positive pole or anode (*anelectrotonus*). This is Pflüger's[4] well known law and can now be explained by our knowledge of bioelectric currents. The closing contractions, elicited with weak and moderate stimuli are due to a depolarization at the anode.

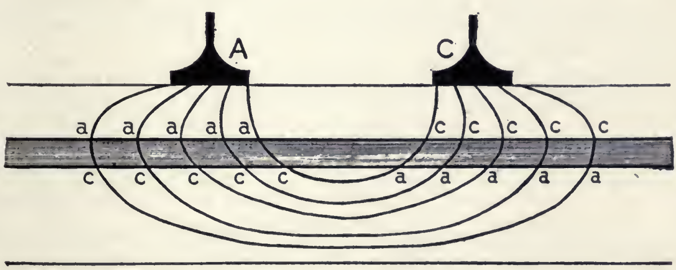

Fig. 72.—Diagram illustrating effects of the anode and cathode on human nerves. *A*, *C*, physical poles of electrodes applied to skin; *a*, *c*, physiological poles in underlying nerve—*a* and *c* beneath *C* correspond to *a′*, *c′*, in text description. (Wiggers.)

It is important to know that the changes of irritability which develop immediately on closing a current do not persist in a static state while the current continues to flow. Furthermore if the anode and cathode are applied over human nerves the effects are complicated by the spread of current through the tissues as shown in Figure 72. As is easily visualized under each physical anode and cathode (*A–C*) there exist what may be termed a pair of physiological anodes and cathodes (*ac* and *a′c′*). When the current is closed the excitation could develop at either physiological cathode (c or c'), but as the density of the current is greater at c', the closing contraction originates at this point. As the current strength is increased it also develops at c. In accordance with Pflüger's law, still stronger currents are required, however, to produce excitation at the physiological anodes a and a', but as the density of current is greater at a than at a' it will arise at a' last and only when currents are exceedingly strong.

We may therefore align the sequence of responses as follows, with regard to the physiological poles: c' and c on closing, a and a' on opening. In practice, however, these are referred to the physical electrodes applied (A and C), hence the sequence.

Cathode closing contraction (CCC),
Anode closing contraction (ACC),
Anode opening contraction (AOC),
Cathode opening contraction (COC).

Nerve Block.—Passage of an impulse through a nerve can be impeded or prevented entirely by mechanical or chemical agencies as well as by the anodal effects of the direct current. This means that functional block can be produced without cutting or injuring the fibers permanently. The "electrotonic" interruption of the conduction of stimulation only occurs with stronger currents and is considered to be due to deep secondary chemical and colloidal processes on the nerve membrane causing a reversal of the normal process of irritability.

Electrical Excitability.—The power of a muscle to respond to an electrical stimulus is a complex function dependent on a number of variable factors which make quantitative measurements difficult. The muscle contraction will vary according to the intensity of the electric current applied, the duration of the stimulus and the rate of development of the current. Irritability is also altered by changes in the length of a muscle or the degree of stretch. Insofar as possible these variables must be controlled or measured when testing muscle excitability.

Strength–Duration Curves.—In clinical practice a minimal or threshold contraction is chosen as the index of response, as it can be more accurately repeated than a sub-maximal response and maximal stimuli are usually too painful to be tolerated. The rate of propagation of the stimulating current or its wave form may be held constant in character depending on the choice of stimulator. The two variables remaining are the intensity of the stimulus and its duration. The excitability of muscle can be determined then, by taking a constant index of response, a constant wave form of stimulating current and measuring the intensity of current required to produce the response when it is applied for a measured duration. The results of such measurements at varying intensity and duration of stimulus may be plotted in the form of a strength-duration curve which gives a graphic index of excitability. (Fig. 73.)

Several different types of stimulators may be used for this purpose including rheotomes, condenser discharges, or more recently electronic stimulators which produce currents of rectilinear wave form.

Chronaxie.—If a long duration or constant current is used to stimulate a muscle or nerve, the intensity which is just sufficient to cause a threshold contraction has been called by Lapique the RHEOBASE. He also introduced the idea of doubling the rheobasic current arbitrarily and of determining the shortest time interval that it must act in order to produce a minimal reaction. This time is called CHRONAXIE. By referring to the graph of the strength-duration curve (Fig. 73) it can be seen that the chronaxie of a tissue is determined by measuring an arbitrary point on the curve. It is obvious that chronaxie is a reciprocal of excitability; decreased chronaxie signifying increased excitability and *vice versa*. Chronaxie determination has become of practical importance in electrodiagnosis as a fairly exact index of excitability although it does not give as complete information as the whole strength-duration curve.

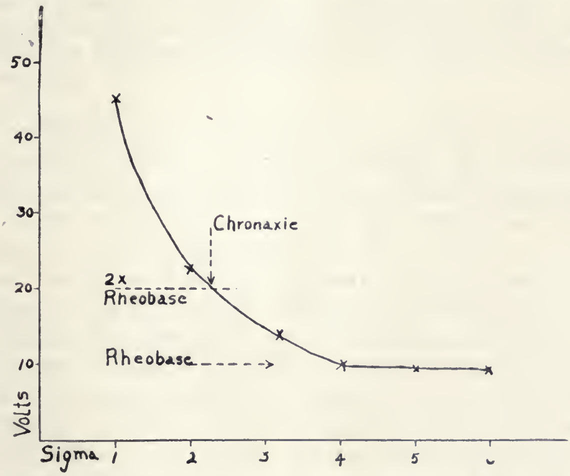

FIG. 73.—Diagram illustrating excitation time, rheobase and chronaxie.

Progressive Currents.—As previously mentioned the response of a muscle to stimulation by an electric current is influenced by the rate of propagation of the current as well as by the intensity and duration. Experimental work has shown that in normal muscles, as the current gradient decreases, the current strength required for excitation increases. Currents which increase linearly or exponentially are called progressive currents and have been used both for electrodiagnosis and for treatment of denervated muscles. (See next Chapter.)

Intensity-Frequency Relation.—Another measure of excitability has been the response of nerve and muscle to sinusoidal alternating currents of different frequencies. With this type of current both the duration of the stimulus and the rate of rise vary according to the frequency. At high frequencies the gradient is steep and the duration brief, while at low frequencies the rise is slow and the duration long. As stimulators supplying a wide range of frequencies are not generally available there is little experience to indicate their value in clinical use. An increasing amount of clinical and laboratory studies indicate that low-frequency sinusoidal currents are of value in treatment of denervated muscles. (See Chapter XXVIII.)

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CHAPTER VII

ELECTRODIAGNOSIS

General Considerations. Principles of Electrodiagnosis. Motor Points. General Technique. Difficulties in Testing. Testing Charts. The Faradic and Galvanic Test. The Reaction of Degeneration. Course of the Reaction of Degeneration. Diagnostic Significance. Testing for the Reaction of Degeneration. Diagnostic Limitations. Other Changes in Electrical Reactions. Increased Excitability. Diminished Excitability. Limitations of the Faradic and Galvanic Tests. Newer Methods of Electrodiagnosis. Testing by Strength Duration Measurements. Testing by Chronaxie Measurement. Testing by Progressive Currents. Electromyographic Diagnosis.

General Considerations.—Electrodiagnosis deals with the reaction of muscles and motor nerves to electrical stimuli. It furnishes a valuable aid from the standpoint of diagnosis, prognosis and therapy in pathological conditions of the motor tract, including the brain, the spinal cord and the peripheral nerves as, also, of the muscles.

Every practitioner of medicine who has occasion to examine and treat nerve injuries and lesions of the central and peripheral nervous system should be able to carry out an electrodiagnostic examination. A physician skilled in electrical testing of muscles and nerves can testify as an expert and, if necessary, demonstrate his findings in court in the cases of paralysis, real and simulated, now so numerous following industrial and other accidents. Turrell states: "The special value of the electrical tests is that they afford objective evidence in place of the subjective signs afforded by the other methods of observation. We may suspect, from the appearance of th skin and from the tone of the muscles, that the loss of voluntary power inea limb is only functional; but a very brief examination of the muscles of this limb by the faradic current will definitely prove to us, if the muscles co ntract, that the case is a functional one, and if no contraction is elicited that there is an organic nerve lesion."

Electrical stimulation of muscles and nerves has for over a century formed part of the large field of physiology. The principle of electrodiagnosis was discovered by a Frenchman, Duchenne and were further developed by French and German physiologists, among them Erb, Remak, Pflüger, DuBois-Reymond and Babinski, until the classical method of testing by the faradic and galvanic currents was fully established. Newer English and French investigators, Lewis Jones and, later, Lapicque, Bourguignon and Adrian, developed modern methods of greater precision. One of these is the testing by condenser discharges, using electrical impulses of definite strength; the other is the determination of the chronaxie.

We have seen in the foregoing electrophysiological considerations that each skeletal muscle possesses the property of independent irritability and contractility if artificial stimuli are directly applied to it. Likewise, any nerve fiber may be stimulated by artificial means at any point of its course. Electrical stimulation is the most effective and convenient artificial stimulant of both muscle and nerve. A suitable electrical stimulus applied to a motor nerve elicits a contraction in all of the muscles supplied by the nerve below the point of stimulation. A suitable electrical stimulus applied to a muscle elicits a contraction of the muscle itself and may also spread to the neighboring muscles. The character of the response varies with the nature and strength of the stimulus employed and the normal or pathological state or the nerve or muscle.

Many of the pathological conditions in the central and peripheral nervous system are accompanied by typical changes in the electrical reaction. It may be normal, it may be exaggerated, it may be diminished, or changed in character, and it may be entirely absent. Under normal conditions all muscle stimulation occurs through the more excitable nerve fibers. After damage of the nerve supply the muscle degenerates, a quick stimulus does not elicit response in either nerve or muscle. A longer and more powerful stimulus however, will still bring about a response in the muscle. Lack of any response to either muscle or nerve stimulation proves that there is neither conductive nerve tissue nor contractive muscle tissue present. This occurs only in the later stages of peripheral nerve injuries or in poliomyelitis or in progressive muscular atrophy.

TABLE 12.—CHANGES IN ELECTRICAL REACTIONS

Quantitative changes	(*a*) Hyperexcitability
	(*b*) Hypoexcitability
Qualitative	(*a*) Contraction sluggish
	(*b*) Contraction persists
	(*c*) Contraction quickly ceases
Qualitative-quantitative	(*a*) No response to faradism (brief stimulus)
	(*b*) Sluggish response to galvanism (long stimulus) (reaction of degeneration)

Using the electrical reactions of nerves and muscles as aids in diagnosis, one must always bear in mind that these tests are only part of the evidence, the other part being supplied by the clinical examination of the muscular power, the reflexes and of the sensory condition of the region affected. A knowledge of the clinical pathology of the central and peripheral nervous system is, therefore, equally essential for the proper interpretation of the findings.

Motor Points.—Strong electric stimuli applied to any muscular part of the body will cause disagreeable shocks and muscular jerks in a widespread area. In contrast to this, electrodiagnosis is a delicate and relatively painless procedure which elicits a well-localized muscular response with a minimum amount of current. Every nerve and every muscle, unless deeply covered by other muscles, possesses a small area where it is most easily excited and where a visible contraction can be elicited with a minimal amount of stimulation. This area is called the motor point. The motor point of a normal muscle is located usually about the middle of the muscle belly, where the motor nerve enters the muscle. In a nerve trunk the motor point can be found where the position of the nerve is nearest to the skin and consequently its shape is somewhat linear. There may be several points of maximal irritability in the course of a long nerve.

The topography of motor points was first studied by Erb, and a set of diagrams based upon his studies is shown at the end of this volume. A set of motor point charts is an indispensable part of the equipment of the beginner; those doing electrical testing should frequently practice the finding of motor points. Even within normal limits there are individual differences in their location and sensitiveness to electric stimulation. In pathological conditions leading to a reaction of degeneration the motor point of a muscle is displaced distally, and the motor points of a nerve disappear entirely.

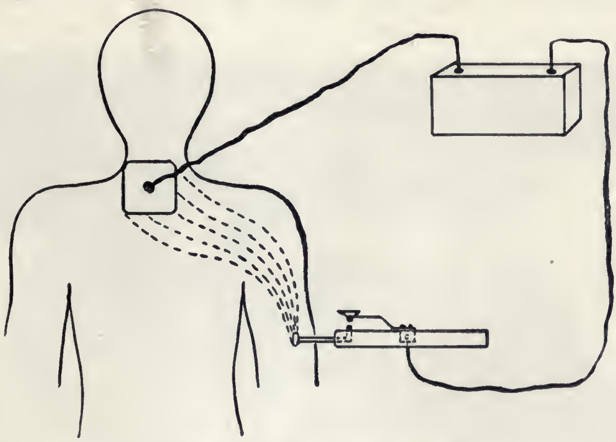

Fig. 74.—Applying electrical stimulus over motor point.

Apparatus and Accessories.—The apparatus for the classical method of testing by the faradic and galvanic current consists of a faradic coil and galvanic generator as described in Chapters VIII and IX. In the more recent thermionic low frequency generators there is usually a current labeled "faradic" available, produced either by a suitable vacuum tube or by a small faradic coil within the generator.

Fig. 75.—Electrode for nerve and muscle testing.

The accessories for electrodiagnosis are: (1) an active or testing electrode, consisting of a small metal disc, covered with asbestos or chamois or several layers of gauze, and mounted on a handle with an interrupting device (make and break key). This electrode serves to concentrate the current over motor points and allows for its make and break. For nerves and small muscles, a disc of about $\frac{3}{4}$ inch in diameter is suitable; for larger ones, one of $1\frac{1}{2}$ inches in diameter. Applying the large disc edgewise also limits the contact surface; too much current crowded into a small electrode causes pain, however. For bipolar testing two active electrodes are employed. (2) A dispersive (indifferent) electrode, large enough to avoid a current density which may give rise to a painful sensation or contraction under that electrode. A 2 by 4 inch or 3 by 5 inch, or even larger plate, covered with gauze or asbestos is usually satisfactory.

De Yong has constructed a simplified device for testing with the interrupted galvanic current only, as illustrated in Figure 76. It combines in one single holder the active electrode and an adjustable dispersive one and offers the advantage that it is light in weight, portable and also enables muscle stimulation for therapeutic purpose.

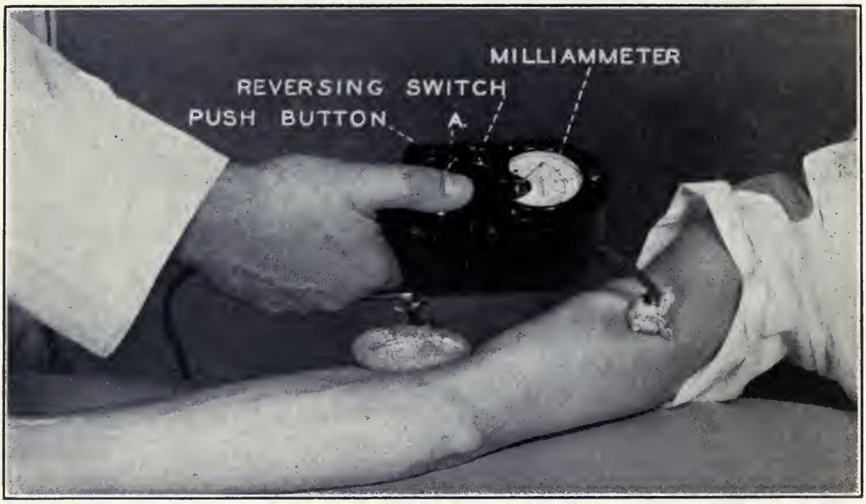

FIG. 76.—Bipolar testing electrode. (de Yong.)

FIG. 77.—Position of patient and operator for electrical testing. (International Clinics, courtesy of J. B. Lippincott Company.)

General Technique.—Practical working knowledge in electrodiagnosis must be acquired by testing normal muscles and nerves and thus learning to appreciate the range of normal variations. It is well to start on a muscle or nerve that is easily located and the response of which can readily be observed, such as the biceps of the arm. A routine for making an electrical examination may be as follows:

The room must be well lighted so that the slightest response of muscles can be observed, and warm so as to avoid chilling of the patient.

The patient and the operator should be placed in a comfortable position so as to avoid undue fatigue. The operator should be able to reach all parts of the apparatus without changing his position. For testing the upper extremity, neck, shoulder and face the patient may be seated at a small table, resting his arm on it; the examiner sits at the opposite side of the table. For the examination of the lower extremity and the back region the patient should lie on a table. A supported position of the parts to be tested is essential for relaxing the muscles.

The area to be examined should be warmed up by a heat lamp, by hot towels, or by immersion in a hot whirlpool bath. The hyperemia produced decreases skin resistance and will also minimize the painfulness of the testing. Electrodes should be well moistened by soaking in hot water, a pinch of table salt added to the water is sufficient to improve its conductivity. A small basin of salt water should be on hand and the testing electrode should be frequently soaked in it during the course of a longer test.

The routine procedure for testing and treatment is *unipolar testing*. The dispersing electrode is placed over any part of the body with little muscular tissue, such as the chest, the small of the back or the sacrum. Firm contact is secured by the weight of the patient by a small sandbag or by bandaging. The testing or active electrode is placed directly over each motor point to be tested.

With any form of electrical testing a certain inertia of muscles has to be overcome at first. For this reason at the beginning more current is needed; after a contraction or two have been elicited usually less current will be necessary for a response. It is best to first turn on a current of moderate strength and, on decreasing it gradually, ascertain thc minimum strength, which is just enough to cause response. In paralyzed muscles often the only response that can be elicited is a slight contraction palpable over the muscle tendon. After the first response, one may slightly shift the testing electrode in order to find a better location of the motor point and thus elicit response with less current. The response of adjoining muscles caused by spreading of electrical impulses is often disturbing. It occurs especially with very weak muscles, and under such circumstances experience is required to recognize slight contractions.

Electrical testing done by experienced operators is rarely painful. Young children with infantile paralysis may be tested without much crying, once they are coaxed over the preliminaries of their unusual experience.

Difficulties in Testing.—As to technical difficulties, it is seldom that the apparatus gets out of order. It may happen that after the electrodes have been applied, the galvanic current turned on and the controls advanced, the patient feels no sensation at all and no muscular response occurs. One may note also that the needle of the milliampere meter does not move. If one persists in turning on more and more current, under such circumstances, the patient may experience a painful shock quite suddenly and the meter needle swings way over. All of this is usually due either to a break in one of the conducting cords or to insufficient moistening of the electrodes. The greater strength of current suddenly overcomes the added resistance, but rudely shakes the confidence of the patient by the sudden shock. New pad electrodes need more moistening than old ones. The addition of a few pinches of salt to the water helps conductivity. The metal plate underneath the pad is subject to gradual wear by electrolytic corrosion and the connection for the cord tip soldered on the plate also corrodes in time. For these reasons as soon as ready made pad electrodes show sign of trouble they are best discarded.

Before stating that any muscle shows total lack of response to any electrical stimulation, one should bear in mind that skin resistance, much edema of the tissues or spreading of current to neighboring muscles, at times may temporarily prevent a response to the galvanic test. In any doubtful case repeated and careful examination is required.

FIG. 78.—Bipolar muscular stimulation. This concentrates the current over a weak muscle and tends to avoid "splashing" of current to adjacent normal muscles.

Bipolar testing consists of placing two small disc electrodes directly over the belly of each muscle to be tested. This furnishes more current density over the testing area, and does away with the spreading of excess current to surrounding muscle groups. The bipolar procedure is employed in exceptional cases only, when the muscles are very weak and the testing current tends to spread, causing contractions in neighboring muscles. A combination of the two methods can be used. For instance, in testing the intrinsic muscles of the hand the palm of the hand is laid over the dispersing electrode and the testing electrode is placed over the interossei on the back of the hand.

Testing Charts.—An accurate record should be kept of the result of electrical testing and all further tests should be likewise recorded.

Tables 15, 16 and 17 show part of the charts used by the author for clinical recording of muscle and nerve tests; in the originals there is room for one or two more subsequent examinations. In each examination there is a column for recording the faradic and galvanic testing and the third column serves for entering the result of either condenser or chronaxie testing. In the motor point charts in the Appendix the relative excitability of muscles and nerves has been indicated by numbers from 1 to 4.

The Faradic and Galvanic Test.—The faradic current applied to a normal muscle or motor nerve elicits a continuous (tetanic) contraction during its entire flow. The galvanic current applied to a normal muscle or motor nerve does not elicit any contraction while flowing steadily, but it causes a brisk single (clonic) contraction whenever it is *suddenly* started or interrupted (made or broken) in a flow of sufficient strength. These contractions are always the result of the *indirect* stimulation of the muscle through the nerve fibers of the motor nerve. Under normal conditions the nerve fibers are more excitable than the muscle. Only when the motor nerve is in a pathological state and cannot be stimulated does the independent property of contraction of the muscle become evident. Such response, however, is of different character; it is sluggish and worm-like instead of the normally brisk contraction.

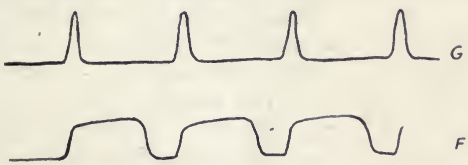

FIG. 79.—Graph of electric response of muscles. *G*, single brisk contraction on stimulation with interrupted galvanic current; *F*, tetanic contraction on stimulation with faradic current.

(*a*) *The Faradic Test.*—The dispersing electrode is connected to one binding post of the faradic coil (it makes no difference to which one), and the testing electrode is connected to the other. The active electrode, well moistened, is placed in good contact, over the motor point of the muscle or nerve to be tested. Turn on the current, slightly advance either the secondary coil or the intensity control in the generator, then press the key of the interrupting handle. The patient will feel a slight stinging sensation under the testing electrode; if the current strength is sufficient, and the electrode is in the correct position, a tetanic contraction of the muscle or group of muscles occurs. This contraction will persist while the current flows. After the first response cut down the current strength to just enough to cause a visible contraction. Also try, by shifting of the testing electrode, to locate the motor point more accurately. *In routine testing normal faradic response usually obviates the necessity of a galvanic test.* If, by comparison with the normal side, there is more current needed to get a response note the position of the secondary coil on the scale.

(*b*) *The Galvanic Test.*—The dispersing electrode is connected to the positive and the testing electrode to the negative terminal of the galvanic supply. Place the testing electrode over the motor point. Advance the rheostat slowly, increasing the strength of the current from zero upward. Then, pressing the key down from time to time, watch for the first visible contraction. By a little practice one should learn to find the threshold of excitation, *i. e.*, the minimum amount of current necessary for a response. As the testing is being repeated, the needle of the milliampere meter will swing out further and further with the same rheostat setting. This is due to the fact that the repeated passage of the current decreases skin resistance.

Why are two currents necessary for testing? The fact that two kinds of current are used for testing is somewhat bewildering for the beginner, Motor nerve fibers are stimulated by the make and break of any current or any sudden change in its intensity, but do not respond to a current which flows steadily without a change in strength. The faradic current consists of rapid and short impulses, each rising to a maximum in about $\frac{1}{1000}$ second and recurring about 100 times in a second. One stimulus occurring in rapid succession after the other keeps a normal muscle in tetanic contraction during the entire time of flow. This makes observation of the response very easy. The galvanic current, while flowing steadily, furnishes no stimulus for muscular response; only when its flow is suddenly started at sufficient strength, or is interrupted while flowing at sufficient strength, does muscular response occur. The response to galvanic stimulation occurs in single contractions. It has been estimated that the impulse of the make and break of the galvanic current through the testing electrode lasts about one-half second.

For ordinary testing we have thus a stimulus of very brief duration—the faradic current, and one of relatively long duration—the make of the galvanic current.

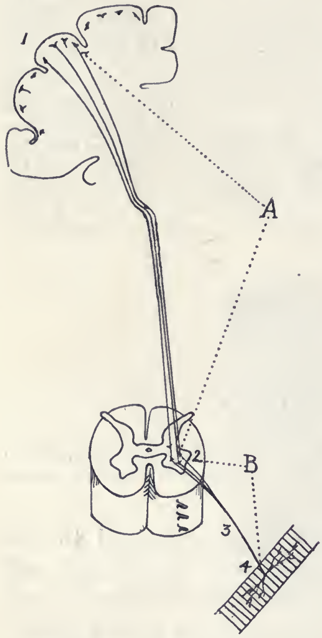

FIG. 80.—Diagram of the motor tract. *A*, Central or upper motor segment; begins with the psychomotor cells in the cortex (*1*) and continues through the pyramidal tract, the lateral columns of the spinal cord to the terminal arborization in the horns (*2*) of the cord. *B*, Peripheral or lower motor segment; it begins with the ganglion cells in the anterior (ventral) horns of the spinal cord (or the motor nuclei in the cerebral nerves) and continues through the peripheral motor nerve (*3*) to the end-plate (*4*) over a muscle. The trophic center of muscles is located in the anterior horn cells; any lesion above the trophic center results in spastic paralysis, slight atrophy, increased reflexes and absence of RD; a lesion below the trophic center results in flaccid paralysis, marked atrophy, lost reflexes and development of an RD.

THE REACTION OF DEGENERATION

The most important use of the faradic and galvanic test occurs in testing for the reaction of degeneration. In the diagnosis and prognosis of lesions of the lower motor neuron of the motor tract this reaction as expressed in the terms of the galvanic and faradic test, is still the standard test and has not been superseded by any of the newer methods of electrodiagnosis.

If due to disease or trauma conduction of impulses through a peripheral nerve has ceased, either by gross anatomical or finer molecular disarrangement of the nerve trunk or the anterior roots, or by a lesion in the spinal cord, within ten days certain well known changes in the electrical reaction occur. These changes are known as the reaction of degeneration or abbreviated, RD. The anatomical changes consist of the breaking up of the affected nerve trunk and of atrophy and later fatty degeneration of the muscles supplied by it. Consequently the nerve loses its electric conductivity and the character of the muscular contraction changes. There is no response to the quick stimulus of the faradic current and only a sluggish response to galvanism; the latter change is due to the fact that only the muscle fibers immediately under the electrode respond and the stimulus then passes to the adjoining fibers, in contrast to the immediate response of all muscle fibers when their nerve supply is intact. The importance of the RD lies in the fact that when present ten days after an injury or disease, it indicates changes in nerve and muscle substance that will take considerable time to recover, and that in a minority of cases may lead to irreparable damage.

The reaction of degeneration may be full, partial, or absolute.

Total or Full Reaction of Degeneration.

(*a*) The nerve does not respond to either faradic or galvanic stimulation.

(*b*) 1. The muscle after a period of hyperexcitability does not respond to faradic stimulation.

2. The muscle responds to galvanic stimulation but demands a greater current strength and the response is *sluggish and slow.*

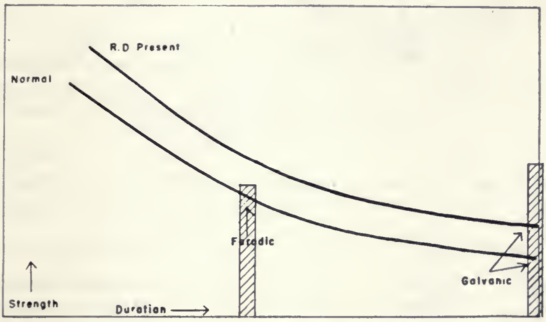

Fig. 81.—Curves showing response to both galvanic and faradic stimulation in normal muscles; absence of faradic response in RD.

3. The motor point is displaced toward the periphery, where the muscle fibers join the tendon (longitudinal reaction).

4. The formula of polar response often changes, *i. e.*, stimulation from the positive pole elicits an equally prompt or often better response than from the negative pole. This change, however, is not constant enough, and for this reason it is the opinion of modern investigators that the polar inversion should be disregarded (page 120).

Partial Reaction of Degeneration.

(*a*) The nerve shows a decrease of both faradic and galvanic responses.

(*b*) The muscle shows:

1. Decrease of faradic excitability.
2. Increase of galvanic excitability (this is irregular, most frequently observed in facial muscles).
3. The response is slow, but this is not as pronounced as in full RD.
4. There may be longitudinal reaction and inversion of polar formula.

Many forms of transition may occur between full and partial reaction of degeneration; partial RD may develop into full RD, and both may simultaneously exist not only in the same extremity but also in the same group of muscles, especially in infantile paralysis.

Absolute Reaction of Degeneration.—This term is applicable to cases in which there is absolutely no response to any current in either nerve or muscle. It represents the final stage of a previous full RD with an unfavorable outcome. It must be made certain always that testing conditions are correct; also it may be better to repeat a test at least once before a definite verdict of hopelessness for the return of function is rendered.

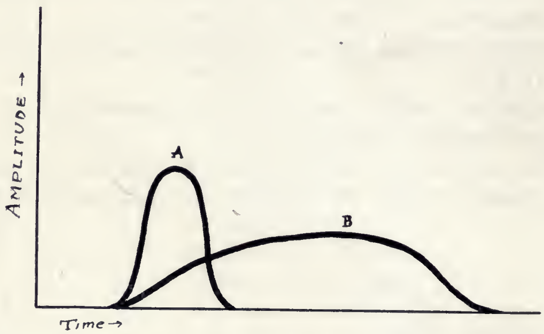

FIG. 82.—Contrast of galvanic response. *A*, brisk response in normal muscle; *B*, slow, sluggish response in degeneration.

TABLE 13.—ELECTRICAL REACTIONS OF MUSCLES AND NERVES

		Faradic	Galvanic
Normal reaction	Nerve Muscle	Tetanic contraction	Brisk single contraction
Partial RD	Nerve Muscle	Diminished response	Diminished response Sluggish contraction
Full RD	Nerve Muscle	No response	No response Sluggish response
Absolute RD	Nerve Muscle	No response	No response

Course of the Reaction of Degeneration.—Whether it is partial or full, the course of the RD always can be divided into three stages:

1. The initial stage lasts from ten days to two weeks. There may be a brief period of hyperexcitability of both muscle and nerve during the first few days. After the first week the nerve loses all response to faradic and galvanic stimulation; the muscles respond but feebly or not at all to the faradic current; galvanic testing, instead of the usual brisk, lightning contraction, elicits only slow and torpid response of the muscles. The average case presents by the middle of the second week all signs of the classical, full RD.

2. The stage of full RD: it lasts from a few weeks to a year or more, according to the severity of the lesion.

3. The final stage: in this there is either a gradual return of the voluntary function and electrical response or absolute RD develops and the outcome is definitely unfavorable.

Figures 83 to 86 show the course of the reaction of degeneration in four typical cases.

Diagnostic Significance of the RD.—The occurrence of the reaction of degeneration signifies a separation—anatomical or physiological—between a muscle and its trophic center and, therefore, may mean any of the following:

1. Complete section of the nerve.
2. Compression due to callus.
3. Degeneration of nerve after interstitial sclerosis (neuroma, hypertrophic interstitial neuritis).

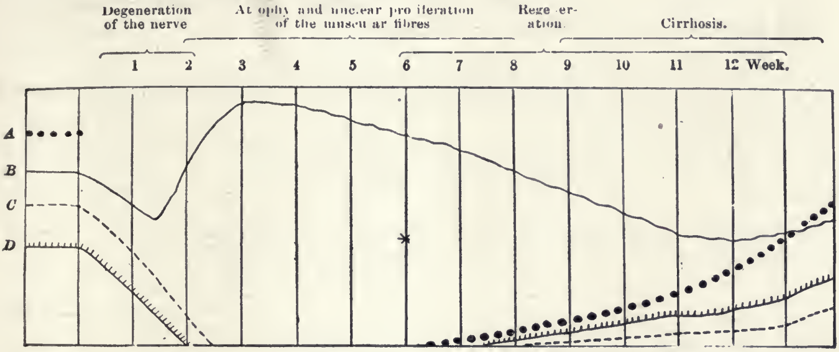

FIG. 83.—Paralysis with relatively early return of motion. (Erb.) *A*, voluntary motion; *B*, galvanic excitability of muscle; *C*, faradic excitability of muscle; *D*, excitability of nerve to either current; *, return of voluntary motion.

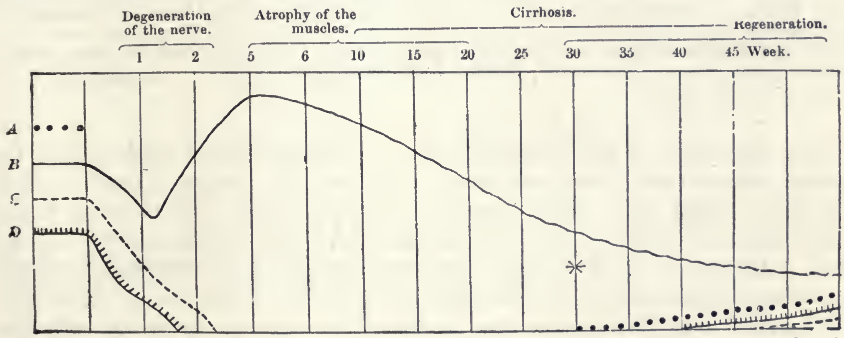

FIG. 84.—Paralysis with late return of motion. (Erb.) *A*, voluntary motion; *B*, galvanic excitability of muscle; *C*, faradic excitability of muscle; *D*, excitability of nerve to either current; *, return of voluntary motion.

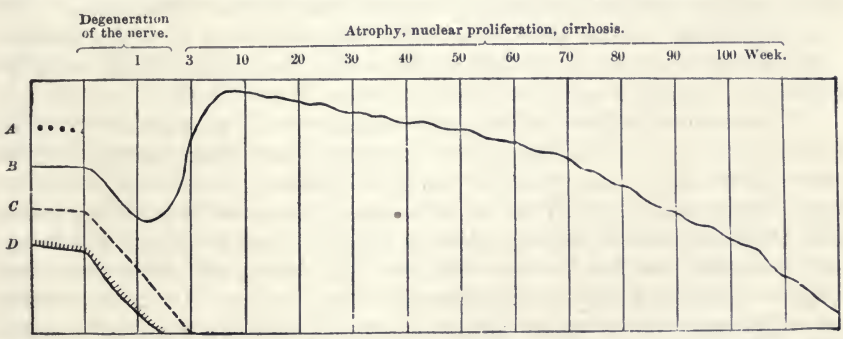

FIG. 85.—Incurable paralysis. Motion lost permanently. (Erb.) *A*, voluntary motion; *B*, galvanic excitability of muscle; *C*, faradic excitability of muscle; *D*, excitability of nerve to either current.

4. Abolition of function of trophic center in the spinal cord due to anatomical lesion in the anterior horns (poliomyelitis, syringomyelia, etc.).

5. Alteration of the peripheral nerve endings due to toxic lesions (polyneuritis following alcoholism, diphtheria, lead poisoning and all forms of peripheral toxic neuritis). In the last type of lesion the RD does not represent all of the changes as in injury of a nerve or in degenerative changes of the spinal cord.

RD is found in the following conditions:

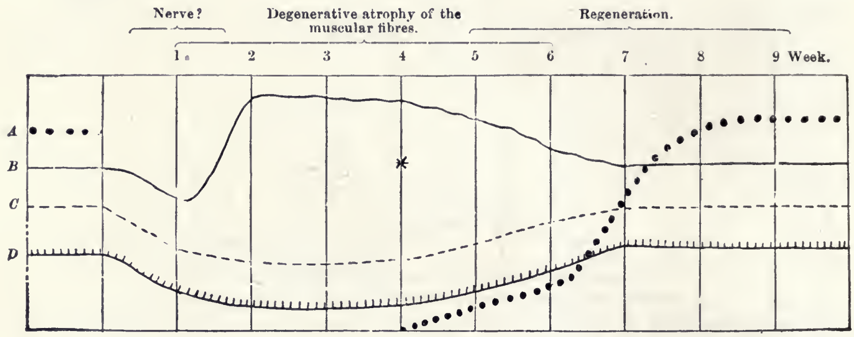

FIG. 86.—Schematic representation of partial degenerative reaction. (Erb.) *A*, voluntary motion; *B*, galvanic excitability of muscle; *C*, faradic excitability of muscle; *D*, excitability of nerve to either current; *, return of voluntary motion. The faradic and galvanic irritability of the nerve and the faradic irritability of the muscle are diminished to a slight extent. Motor power returns at an early period; complete and rapid recovery. Degeneration of the nerve probably absent.

(*a*) Affections of the anterior horn cells of the spinal cord and of the nuclei of the cranial nerves; acute, subacute and chronic anterior poliomyelitis, spinal forms of progressive muscular atrophy (in contrast to the myopathic muscular atrophy), local affections of the spinal cord if involving the anterior horns (transverse myelitis, disseminated sclerosis, hematomyelia, new growths, syringomyelia, new growths in the cord). RD occurs in cerebral conditions when the nuclei of the cranial nerves are affected, because these are trophic centers of equal significance as the anterior horn cells. Bulbar paralysis of various kinds result in full RD in the respective cranial nerves and the muscles supplied by them.

(*b*) Affections of the anterior spinal roots, which may be either primary —due to traumatism, or secondary, due to affections of the spinal meninges (syphilitic) or of the vertebræ (tumors, cancer, tuberculosis).

(*c*) Diseases or injuries of the peripheral nerves. Mechanical or chemical injuries alike may cause degenerative changes in peripheral nerves. Injuries to peripheral nerves may result in complete division, partial division (laceration), compression (scar tissue or callus), and simple bruising. The presence of RD serves as an important guide in diagnosis and prognosis, but it cannot determine whether the nerve has been divided or not. Primary inflammation of the nerve, infections and toxic irritations, as well as inflammations of adjoining tissues, cause various forms of neuritis, classified as toxic (alcohol, lead), infectious (diphtheria, typhoid, influenza), and rheumatic or idiopathic (exposure, polyneuritis). (See Chapter XXVIII.)

Functional, hysterical paralyses and paralyses of cerebral origin are never accompanied by important disturbances of the electrical reactions. At most there is slight electrical hyperexcitability, while in the later stages there is usually hypoexcitability from muscular atrophy. *Therefore, the absence* *of RD may serve as important evidence in determining malingering or functional paralysis* and differentiating them from other conditions.

Table 14 gives the summary of the diagnostic significance of the changes in the electrical reaction in pathological conditions.

TABLE 14.—DIAGNOSTIC SIGNIFICANCE OF CHANGES IN ELECTRICAL REACTIONS

Increased response	Recent hemiplegia, first days of nerve injuries, tetany, spasmophilia, chorea, initial stages of spinal cord diseases	
Decreased response	Advanced hemiplegia, tabes, paralysis agitans, later stages of spinal cord diseases, muscle atrophy due to disuse in arthritis, myositis, mechanical conditions, young children	
Reaction of degeneration (full or partial		*Brain*
	Lesion of bulbar nucleus Compression of intracranial nerve trunks	Labio-glosso-pharyngeal paralysis, softening of centers, tumors, hemorrhage of centers
		Spinal Cord
	Lesions of anterior horns	Acute: infantile paralysis, acute anterior poliomyelitis of adults Subacute: amyotrophic lateral sclerosis Chronic: chronic poliomyelitis
	Lesions of cord, including anterior horns	Syringomyelia, hematomyelia
	Compression of nerve trunks in spinal canal or in spinal origin	Pachymeningitis, tumors, fractures, dislocations
		Peripheral Nerve Trunks
	Traumatic lesions	Section, compression, elongation, concussion
	Toxic neuritis	Alcohol, lead, diabetes, focal infections
	Infectious neuritis	Typhoid, syphilis, influenza, tuberculosis, polyneuritis
	Neuritis from exposure	Facial paralysis, musculo-spiral paralysis
Absolute RD (no response at all)	End of stages of progressive muscle atrophy Long-standing peripheral nerve injuries or old poliomyelitis	

Prognostic Significance of the RD.—The presence of a full RD permits us to state that the seat of a lesion accompanied by paralysis is in the lower motor neuron, the anterior horn cells, the anterior spinal roots or in the peripheral nerve. It does not permit any more accurate location.

It also denotes the severity of a lesion, and the fact that it is an organic one because of the marked pathological changes upon which it is based. It has no relation whatever to the etiology of the lesion, because trauma as well as inflammations and new growth can produce RD.

The chief significance of the reaction of degeneration is that it indicates changes in nerve and muscle substance that will take considerable time, months, at least, for recovery. The existence of an RD by no means indicates an irreparable damage. It is only a stage of reaction and not a permanent phenomenon, because the lesion may gradually improve and full restoration may occur. On the other hand, if the lesion of the lower neuron is not arrested, the muscles will become fully atrophied and absolute RD follows, and all response to electrical stimulation ceases.

The presence of a partial reaction of degeneration shows that changes have occurred in the terminal muscular branches of some of the nerves while others have remained approximately normal. The latter have, therefore, retained their electrical excitability. A partial reaction of degeneration always permits a more favorable prognosis as to the expected recovery than a full reaction of degeneration. It also indicates the necessity of continued observation and the repetition of the electrical tests.

The absence of reaction of degeneration allows the conclusion that no gross anatomical changes are present in the nerve anywhere, and that one may expect an early recovery, possibly in three or four weeks.

The prognosis based on electrical testing is of especial value in such rather frequent types of paralysis, as facial paralysis following exposure, paralysis of extremities due to pressure or exposure (wrist-drop after sleeping with arm under head), and in infantile paralysis. Testing in these conditions, about ten days after onset, enables one to differentiate between mild, moderately severe and severe cases. When there is no RD there is usually recovery in two to four weeks; if there is partial RD present recovery may take six to twelve weeks; if complete RD is found recovery will take at least six to twelve months. In organic spinal affections, as well as in peripheral toxic neuritis, no definite prognosis can be made on the basis of partial or full RD alone because it may represent only a transitional stage in an otherwise progressive and incurable condition.

Testing for the Reaction of Degeneration.—The preparations of the patient are made as described previously. A motor point chart is an indispensable aid for beginners (see charts in Appendix of this volume).

The usual plan of testing is as follows:

1. Testing with the faradic current (*a*) nerve and (*b*) muscles.
2. Testing with the galvanic current (*a*) nerve and (*b*) muscles.

Beginners should remember in testing one-sided lesions to begin on the normal side for comparison and for easier finding of the motor points. They should also bear in mind that in RD motor points of muscles are displaced toward the periphery and motor points of affected nerves are lost altogether. It is the rule to begin with the faradic test because if it is normal there is usually no need to proceed further. In real paralysis, however, and in the presence of full RD it may be less painful to begin with the galvanic test, as it permits the location of motor points with less current. Once the motor points have been found, the testing electrode may be left in position and the faradic test can be done with less pain.

Before commencing electrical testing one should always endeavor to get an idea of the active voluntary muscular power present. Muscles capable of active contraction almost always respond to faradism. Testing for skin sensation gives a lead in case of mixed nerve involvement. For instance, anesthesia over part of the deltoid area points to paralysis of the circumflex nerve (see Figs. 301 and 302).

The Polar Formula.—We have seen under electrotonus that the order in which muscular contraction appears in normal muscles is presented as C.C.C. > A.C.C. > A.O.C. > C.O.C., signifying that cathodal closing (the make of the current with the negative pole) excites contraction with the least amount of current; more current is needed for anodal closing and still more for the anodal opening, and most for the cathodal opening contraction. It has been proven by modern investigators that at the make of the current stimulation occurs chiefly at the negative pole, and at the break of the current, at the positive pole. The generally accepted view is that at the make (closing) of the current the negative pole alone is active and at the break (opening) only the positive pole.

In ordinary clinical testing practice one may disregard the polar formula; galvanic testing should always be done with the negative pole as the active pole and with the "make" of the current.

Diagnostic Limitations.—The presence of an RD may be a deciding factor in diagnosis, but it is not infallible. It must always be considered in conjunction with other clinical evidence. For instance, in both anterior poliomyelitis and peripheral nerve lesion flaccid paralysis and rapid muscle wasting occur and the typical reaction of degeneration develops. In poliomyelitis there is no sensory change, because only the motor cells of the anterior horn are out of function, while in peripheral nerve lesions, the sensory fibers being included in the common nerve cord, there are always definite sensory changes. The distribution of paralysis in poliomyelitis is irregularly located in the various muscles (with some well-known sites of predilection) and does not correspond with any particular peripheral nerve.

Another example of the difficulty of making a diagnosis on the basis of nerve tests alone are multiple injuries of the extremities, especially of the forearm. Extensive scar formations and adhesions, due to longitudinal incisions or multiple infectious processes, result in a loss of response of several muscles, thus imitating a nerve lesion. A nerve lesion might also be aggravated or appear more extensive from the coexistence of tendons bound down by adhesions. Electrical testing without a thorough clinical examination in paralysis of traumatic origin cannot determine whether the paralysis is caused by the original trauma or secondarily by contracting scars or pressure of callus. The possibility of a coincident systemic infection must also be borne in mind.

OTHER CHANGES IN ELECTRICAL REACTIONS

Increased Excitability.—Increased excitability to electrical stimulation occurs in pathological conditions of the nervous system where there exists a state of irritation of the brain centers or where the brain has lost its inhibitory influence upon the peripheral nerve tracts. Recent hemiplegia, early stages of brain tumor, first stages of peripheral nerve injuries, acute neuritis and the early stages of progressive muscular atrophy, of sclerosis multiplex and myelitis are characterized by increased excitability. In tetany, spasmophilia, chorea minor, in various occupational diseases or injuries due to the hypertonicity of the muscles, the same condition prevails. Increased irritability, however, is of little diagnostic value; it might aid in a differential diagnosis between tetanus and hysterical spasms; in the latter a decreased excitability is the rule. (See also Table 55.)

Diminished Excitability.—Diminished excitability is much more frequent and occurs in three groups of conditions:

1. In muscular lesions following continued inactivity; in such event, clinically, there appear atrophy, decrease of muscular power and decrease of the reflexes. Prolonged immobilization after fractures or joint affections is a frequent cause for electrical hypoexcitability, as shown in the atrophy of the deltoid after shoulder lesions and that of the quadriceps following injuries to the knee. Electrical testing helps to differentiate this condition from the atrophy following true neuritis because in the latter affection reaction of degeneration is present. The practical importance of these differences lies in the determination of the appropriate method of treat-

ment. In simple muscular atrophy, as signified by simple hypoexcitability, rhythmic electrical stimulation by the surging faradic or sinusoidal current usually results in prompt improvement. Marked hypoexcitability without qualitative changes is usually characteristic of primary (myopathic) muscular atrophies, such as progressive muscular atrophy, pseudohypertrophic paralysis, myotonia and myasthenia, while muscular atrophies of spinal origin invariably show the reaction of degeneration, due to the involvement of the peripheral neuron and after a sufficiently large number of bundles have degenerated.

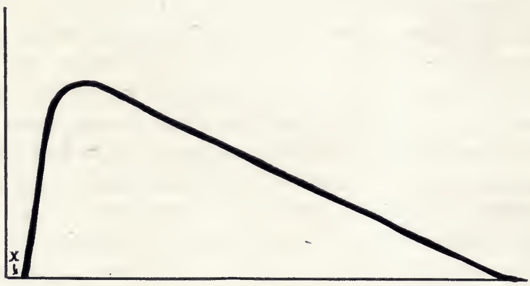

FIG. 87.—Muscle curve of myotonic reaction. Sustained response *X* point of single stimulus.

2. In certain lesions of the peripheral neuron, that are not sufficiently advanced, or are not affecting all fibers of a certain muscle. Early stages of peripheral nerve injuries, chronic poliomyelitis, tract diseases of the spinal cord, certain forms of toxic neuritis may manifest themselves electrically by hypoexcitability instead of a reaction of degeneration.

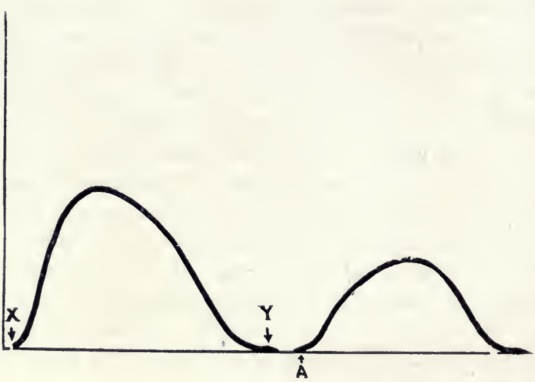

FIG. 88.—Muscle curve of myasthenic reaction *X–Y* time of tetanizing current. *A*, Time of single galvanic stimulus.

3. Lesions of the central motor neuron when there is no change in the peripheral neuron. Late stages of hemiplegia, tabetic paralysis, myelitis, etc., result in simple hypoexcitability, due to muscular inactivity.

Myotonic and Myasthenic Reaction.—These reactions consist in qualitative changes in the electrical response and both are of specific significance in the diagnosis of two typical but rather rare pathological conditions.

The myotonic reaction is characterized by the fact that on faradic stimulation the muscles remain in tetanic contraction for some time, as long as twenty seconds, after the stimulus has ceased. This is characteristic of Thomsen's disease.

The myasthenic reaction consists of an abnormal exhaustion of muscles; after initial normal response to the faradic current subsequent stimulation elicits less and less response, until contractions cease altogether. After a period of rest response returns and the same process can be repeated. This typical reaction serves to corroborate the diagnosis of myasthenia.

Limitations of the Faradic and Galvanic Test.—The classical galvanic-faradic method of testing is easily comprehensible and the apparatus is simple and inexpensive. The technique, however, requires time, patience and exactness and well-grounded knowledge of the anatomy and physiology of the nervous and muscular systems. It is the most important test for the recognition of gross changes in the electrical response of peripheral nerves and muscles. It is evident, however, that the simple faradic and galvanic test is insufficient for exact measurements of the degree of change and for definite measuring of progress or further degeneration. The strength of the ordinary faradic current is not measurable at all, and the length of each impulse varies not only in different coils, but even in the same coil. Faradic response moreover has no prognostic value because in a paralyzed muscle voluntary power returns, as a rule, before the response to faradism. The strength of the galvanic current can be measured, but its duration of flow is not measurable. Both the faradic and galvanic tests are often painful because, as a rule, the currents used for testing are much too strong and last much too long.

Newer methods overcome the limitations of the simple faradic and galvanic test through testing by condenser discharges and chronaxie measuring. These methods allow accurate charting of results, but require more elaborate and more expensive equipment and much more time for testing.

NEWER METHODS OF ELECTRODIAGNOSIS

Testing by Strength-Duration Measurements.—To determine the strength-duration relationship of a current producing a threshold contraction, condenser discharges are usually used for stimulation. A condenser, as described in Chapter II, when electrically charged, stores up an amount of electricity in accordance with its capacity. When discharged through the body it will set up a momentary flow of unidirectional current and its stimulating effects will depend on the capacity of the condenser. Testing by condenser discharges is based on the fact that the discharge of a condenser through a constant resistance varies in duration according to the capacity of the condenser. The discharge starts at its maximum value and falls off gradually, so that with a set of condensers of various capacity it is possible to obtain currents whose total duration varies from $\frac{1}{24000}$ to $\frac{1}{200}$ second. The working of a condenser set can be compared to a set of springs of gradually increasing size kept at even tension. As each spring is released it will oscillate according to its length and furnish an impulse, the duration of which will depend on the length of the spring. Thus the largest spring, representing the largest condenser capacity, will furnish the longest duration of stimulation (Jones).[6]

Stimulators for these tests may consist of progressive decades of condensers varying in capacity between 10 and 0.0001 microfarads. A voltmeter and voltage controlling rheostat are provided so that the threshold voltage may be adjusted and read on the meter for each condenser capacity used. Resistances in shunt and series are coupled in the patient's circuit to

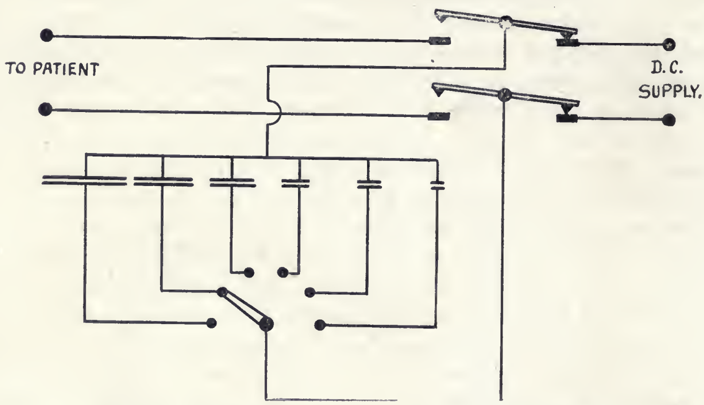

Fig. 89.—Diagram of control of condenser discharges.

Fig. 90.—Graph of discharge of a condenser.

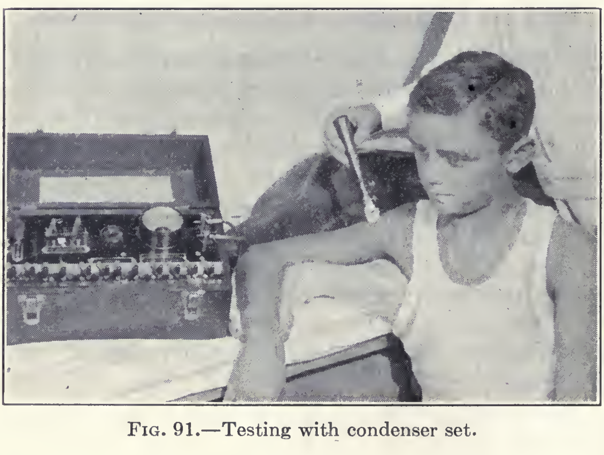

Fig. 91.—Testing with condenser set.

minimize differences in skin resistance. It is convenient to plot the voltage and capacity readings on logarithmic graph paper. If desired the duration of the stimulus may be computed by use of the following equation:

Duration (seconds) = resistance (megohms) × capacity (microfarads).

For example: taking an average resistance of 1000 ohms (0.001 megohms) and a capacity of 1 microfarad and substituting these values in the above equation we find:

Duration time = 0.001 × 10 = 0.01 seconds (10 milliseconds).

If an electronic stimulator is used which provides square waves the duration of each impulse in milliseconds is indicated on a dial of the instrument. The duration of such waves may vary from 20 to 0.02 milliseconds.

The technique of testing is similar to that of the ordinary galvanic test. A large dispersing electrode connected to the positive terminal is placed over a remote part of the body and a small $\frac{1}{2}$ inch wet disc electrode connected to the negative terminal is placed exactly over the motor point to be tested. The largest condenser or longest duration stimulus is used first and the voltage adjusted until a minimal contraction is obtained. A smaller capacity condenser is next tried and the threshold voltage determined. To get even distribution of points on the curve when recording logarithmically it is convenient to use values such as 10, 5, 2, 1, 0.5, 0.2, 0.1, 0.05, etc., microfarads or milliseconds. It is important to be sure that the highest voltages (400 v.) are used only with the smallest condensers or stimuli of shortest duration to avoid painful shocks.

Some observers have found that a small bore needle may be inserted into the muscle as the stimulating electrode. This is not painful after the initial prick and lower current voltages may be used as a just perceptible movement of the needle is taken as the index of response. The reliability of the readings is somewhat enhanced by this technique.

Determination of strength-duration curves is the most accurate clinical method of measuring excitability. Slight changes in both voltage and time factors may be observed which are helpful in detecting evidence of nerve regeneration at an early date. Progressive improvement in the strength-duration curves toward the normal suggests a good prognosis for recovery of function and gives an objective record of progress.

It is at times possible to observe a "break" in the strength-duration curve during nerve regeneration. This is taken to indicate beginning reinnervation of the muscle and may appear before other signs of recovery are detectable.[7]

The drawbacks of the strength-duration method of testing are that it takes considerably more time than ordinary testing and some experience before reliable results are obtained. Commercial apparatus is not readily available and this method is chiefly used in institutions in connection with physiological laboratories.

Bauwens[1] has recently devised an apparatus yielding single impulses of rectangular wave form whose duration was restricted to 1 second, $\frac{1}{1000}$ second and $\frac{1}{50}$ second; by using pentode valves in the output circuit, current could be measured and remained unaffected, within reasonable limits, by fluctuations of resistance. It is desirable that this fairly simple type of testing apparatus should receive large scale clinical testing.

Testing by Chronaxie Measurement.—Testing for chronaxie is based on the electrophysiological considerations outlined in the preceding chapter. It can be seen by referring to Figure 73 that chronaxie is a single point on the strength-duration curve of excitability. As a method of testing its originators were Lapicque[7] and Bourguignon.[2]

In chronaxie testing a current intensity of a known contractile effect upon an individual muscle or nerve is applied; the difference in time necessary to get a contraction is the only variable factor; this can be accurately observed and recorded. The unit of measurement is the Sigma—σ—representing $\frac{1}{1000}$ of a second and is recorded like condenser testing in decimal figures from 0.1 to 10 or more.

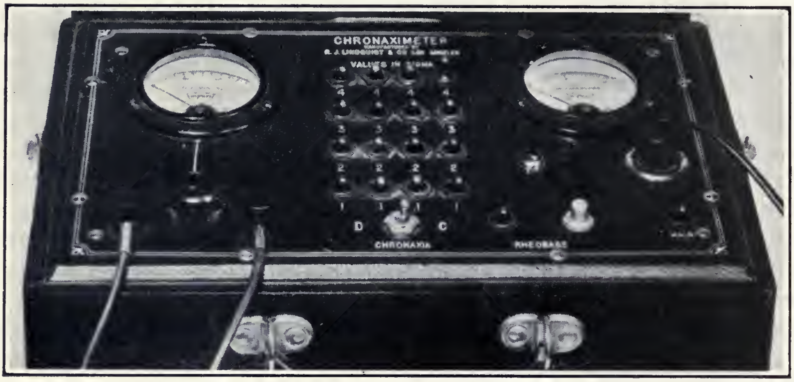

Fig. 92.—Chronaxie meter. (Courtesy of R. J. Lindquist.)

For chronaxie testing *chronaxie meters* serve; and a control board of such an instrument is shown just above. The instrument produces a galvanic current which serves to determine the rheobase—the minimum amount of current necessary for response in an individual muscle and nerve. A milliammeter and voltmeter on the panelboard give a reading of this current intensity. The instrument also contains a series of condensers which can be progressively charged and discharged until the condenser giving the value of the chronaxie is found.

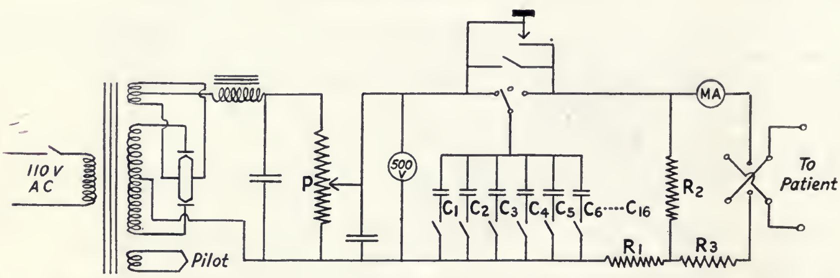

Fig. 93.—Circuit of chronaxie meter (Lindquist). *C, C, C, C, C,* values selected for discharge intervals as indicated on panel. Direct-reading range is from 0.01 to 111.10 sigma.

Technique.—The first step in chronaxie testing is to ascertain the weakest current without regard to its duration, which applied to a nerve or muscle produces the faintest perceptible contraction. This is done by unipolar testing with the galvanic current of the chronaxie meter, using the negative pole as the active pole. The testing electrode is placed over the motor point and the current is allowed to flow at a gradually increasing strength; from time to time one "makes" the current over the motor point with the rheobase switch until with a certain current strength a minimum contraction occurs. The voltmeter records the amount flowing and this voltage required for a minimal response with the make of the current is called the single rheobase or the threshold of excitation. Next, with the current increased to read exactly double the rheobase value as observed on the voltmeter and with the testing electrode on the same point, one charges and then discharges a series of condensers. By successive discharges one arrives at the condenser capacity just sufficient to produce a contraction equal to that obtained with the single rheobase and this is the value of the chronaxie. This is a time dimension because it refers to the rate of discharge of a condenser. It is recorded in decimal system as stated.

The advantage of chronaxie meters is that as long as the position of the testing electrode is unchanged, the chronaxie is not influenced by the skin resistance and the position of the muscle and allows, therefore, more accurate testing and recording.

When the motor nerve of a muscle has undergone degeneration, the muscle also degenerates and we find certain alterations in its chronaxie. For some time after section of the motor nerve the chronaxie of nerve and muscle remains unaltered; this period may last a week or ten days. After this the chronaxie becomes very high; 20 to 100 times the normal amount.

Chronaxie testing furnishes constant values for the purposes of accurate charting and has enabled important conclusions to be drawn as to functional and embryological similitudes.

Bourguignon[2] made the important observation that different muscles (with their nerves) have different chronaxies, and further, that in the same segment of a limb, muscles of similar function have the same chronaxie. Thus, when the chronaxie of flexor and extensor muscles is compared, it is found that the flexors have a chronaxie only half as great as the extensors. The chronaxie increases toward the periphery and thus is greater in muscles in the same functional group, when these are situated more distally. It is the same whether the muscle is stimulated directly or through the nerve.

Chronaxie has been criticized by physiologists as a measure of excitability, because of its arbitrary and empirical character and because the type, shape and position of electrodes alter the results (Davis[4]).

Testing by Progressive Currents.—Testing by progressive currents has been recently described by Pollock *et al.*[8] The principle of this procedure is to use, instead of the sudden make and break of a galvanic current or the discharges of a condenser, a current with slow rate of rise and long duration. A modified form of condenser discharge as introduced by Lapicque may be used (Fig. 131) or waves in the form of isosceles triangles as described by Pollock *et al.*[8]

One characteristic of denervated muscle is its response to a slowly rising current, whereas normal muscle because of its ability to accommodate to slow changes in potential does not contract when stimulated by such a current. A sudden increase in the amperage of current necessary to produce a contraction when stimulating a denervated muscle with a progressive current can be taken as an indication that a successful junction between the regenerating nerve and the muscle has been effected.

It is claimed that with this method selective stimulation of sluggish muscle groups is possible, which is especially valuable in partial reaction of degeneration, when there are degenerated muscle bundles mixed with normal bundles. This development is of considerable interest, but its practical utilization for measurement is still to be perfected.

Electromyographic Diagnosis.—The recording of electrical discharges from peripheral skeletal muscles often gives information of value in dif-

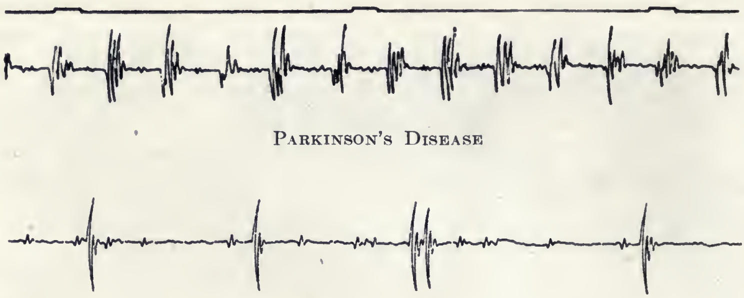

Fig. 94.—Electromyogram of tremor in Parkinson's disease and of fasciculation in progressive muscular atrophy. Time interval, one second on upper signal. (Electromyographic Laboratory, Massachusetts General Hospital.)

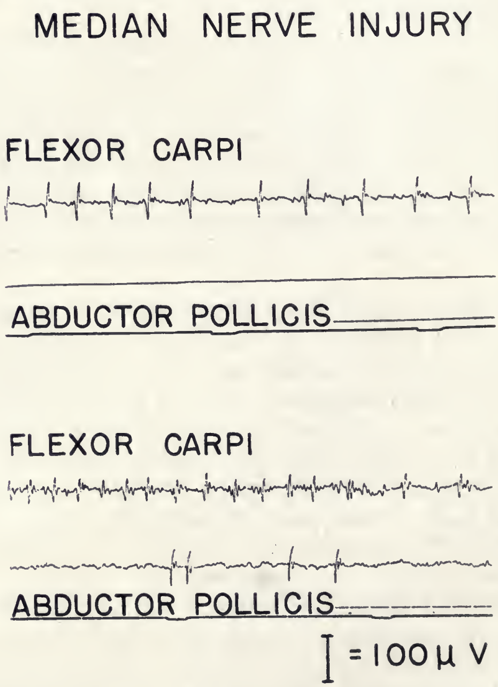

Fig. 95.—Spontaneous discharges during period of recovery. (Watkins and Brazier.)

ferential diagnosis. This is particularly true in the case of tremors and muscular fasciculations and fibrillations. Experience has shown that the tremor associated with Parkinson's disease has a characteristic frequency of about 6 per second which is easily distinguished on the electromyogram from all other tremors such as may occur with hyperthyroidism or hysteria.

(Fig. 94.) Electromyograms have also been useful in the study of athetosis and spastic conditions.[11]

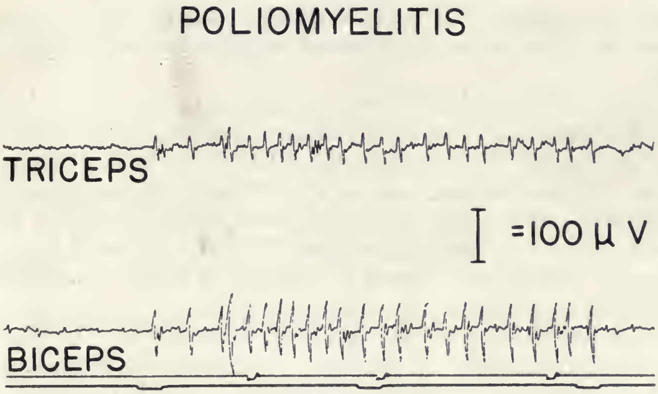

Fig. 96.—Synchronous activation of opposing muscles during voluntary elbow flexion in poliomyelitis. (Watkins and Brazier.)

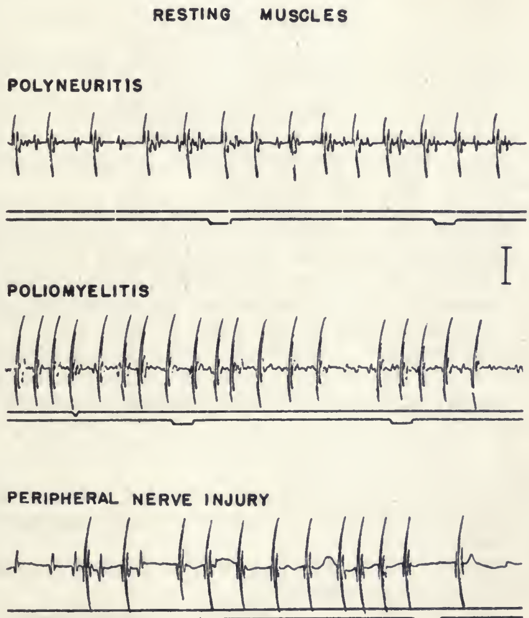

Fig. 97.—Spontaneous discharges during period of recovery. (Watkins, Brazier and Schwab.)

Visible fasciculation and fibrillation of muscles is a recognized essential point in the diagnosis of progressive muscular atrophy and amyotrophic lateral sclerosis. The electromyographic recording of these has a characteristic appearance and at times these discharges may be picked up by this method of study when not observed clinically. (Fig. 95.) The degree of spontaneous electrical activity is also thought to be of prognostic significance.

Any reliable test which indicates beginning reinnervation of a muscle after a peripheral nerve injury is of considerable clinical value. Spontaneous discharges may be found electromyographically before other signs of regeneration are present.[9] Thus this type of examination is useful in following progress after nerve suture or in compression and stretch injuries. (Fig. 96.)

In poliomyelitis studies have been made of the nature of the dysfunction present in the lower motoneuron by means of electromyograms.[10] Hyperirritability or "spasm" has been demonstrated; also disordered reciprocal innervation with simultaneous activation of antagonistic muscles. (Fig. 97.) During recovery spontaneous discharges are obtained similar to those seen in cases of nerve injury and polyneuritis.[3] This method of investigation may be used for judging the effects of therapeutic agents and for following the progress of recovery.

An electromyographic test has also been described for the diagnosis of tetanus in obscure cases.[11] In muscular dystrophy no abnormalities are found and the test is not valuable in diagnosis of this condition. At the present time, electromyography, although of clinical value, is done chiefly in hospitals or medical schools in connection with research projects.

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TABLE 15.—MUSCLE AND NERVE TEST CHART OF UPPER EXTREMITY

I. SHOULDER AND MUSCULO-SPIRAL (RADIAL) DISTRIBUTION

Name................................Number....................Diagnosis....................

		Date			Date		
		Farad.	Galv.	Cond. or chron.	Farad.	Galv.	Cond. or chron.
N. Accessorius and Plexus Brachialis Trapezius..........	R.						
	L.						
Plexus Brachialis. Serratus anterior..........	R.						
	L.						
Pectoralis major (n. thorac. ant. extern.)	R.						
	L.						
Rhomboideus (n. post. scapularis)..........	R.						
	L.						
Supraspinatus (n. suprascapularis)..........	R.						
	L.						
Infraspinatus (n. suprascapularis)..........	R.						
	L.						
Latiss. dorsi (n. subscapularis)..........	R.						
	L.						
Teres major (n. subscapularis)..........	R.						
	L.						
Deltoideus (n. circumflexus)..........	R.						
	L.						
N. Musculo-cutaneus. Biceps..........	R.						
	L.						
Brachialis..........	R.						
	L.						
N. Musculo-spiralis. Triceps..........	R.						
	L.						
Brachio-radialis (Supin. long.)..........	R.						
	L.						
Ext. Carpi Radii Longior..........	R.						
	L.						
Ext. Carpi Radii Brevior..........	R.						
	L.						
Supinator..........	R.						
	L.						
Ext. Carpi Ulnaris..........	R.						
	L.						
Ext. Communis Digitorum..........	R.						
	L.						
Ext. Minimi Digiti..........	R.						
	L.						
Ext. Indicis..........	R.						
	L.						
Ext. Oss. Metacarp. Poll..........	R.						
	L.						
Ext. Brevis Pollicis..........	R.						
	L.						
Ext. Longus Pollicis..........	R.						
	L.						

TABLE 16.—MUSCLE AND NERVE TEST CHART OF UPPER EXTREMITY

II. MEDIAN AND ULNAR DISTRIBUTION

Name...Number......................Diagnosis..................................

		Date			Date		
		Farad.	Galv.	Cond. or chron.	Farad.	Galv.	Cond. or chron.
N. Medianus.							
Pronator Radii Teres	R.						
	L.						
Flexor Carpi Radialis	R.						
	L.						
Palmaris Longus	R.						
	L.						
Flexor Sublimis Digit.	R.						
	L.						
Flexor Longus Pollicis	R.						
	L.						
Flexor Profundus Digiti	R.						
	L.						
Abductor Pollicis	R.						
	L.						
Opponens Pollicis	R.						
	L.						
Flexor Brevis Pollicis	R.						
	L.						
Lumbricales I and II	R.						
	L.						
N. Ulnaris.							
Flexor Carpi Ulnaris	R.						
	L.						
Flexor Profundus Digit.	R.						
	L.						
Palmaris Brevis	R.						
	L.						
Abductor Minimi Digiti	R.						
	L.						
Flex Minimi Digiti	R.						
	L.						
Opponens Minimi Digiti	R.						
	L.						
Lumbricales III and IV	R.						
	L.						
Interossei I–II	R.						
	L.						
Interossei III–IV	R.						
	L.						

Table 17.—Muscle and Nerve Test Chart of Lower Extremity

Name........................ Number........................ Diagnosis........................

		Date			Date			Date		
		Farad.	Galv.	Cond. or chron.	Farad.	Galv.	Cond. or chron.	Farad.	Galv.	Cond. or chron.
N. Femoralis.										
Sartorius	R.									
	L.									
Rectus Femoris	R.									
	L.									
Vastus Internus	R.									
	L.									
Vastus Externus	R.									
	L.									
Pectineus	R.									
	L.									
Adductor Longus	R.									
	L.									
N. Sciaticus.										
Gluteus Maximus	R.									
	L.									
Gluteus Medius	R.									
	L.									
Biceps Femoris	R.									
	L.									
Semitendinosus	R.									
	L.									
Semimembranosus	R.									
	L.									
N. Peroneus (Ext. Poplit.)										
N. Peroneus Profundus.										
Tibialis Anterior	R.									
	L.									
Extens. Longus Digit.	R.									
	L.									
Extens. Longus Hallucis	R.									
	L.									
Extens. Brevis Digitorum	R.									
	L.									
N. Peroneus Superficialis.										
Peroneus Longus	R.									
	L.									
Peroneus Brevis	R.									
	L.									
N. Tibialis (Int. Popliteal)										
Gastrocnemius	R.									
	L.									
Soleus	R.									
	L.									
Flexor Longus Digitorum	R.									
	L.									
Flexor Hallucis Longus	R.									
	L.									
Tibialis Posterior	R.									
	L.									

CHAPTER VIII

THE GALVANIC CURRENT AND ION TRANSFER

Historical. Physics and Apparatus. Polarity. Effects Upon the Body. Physical Effect. Physiological Effect. Therapeutic Forms. Medical Galvanism. Clinical Effects. Indications. General Technique. Regional Technique. The Galvanic Bath. Electrolysis or Surgical Galvanism. Ion Transfer. Physicochemical Considerations. Penetration of Ions. Clinical Uses. General Technique. Applications From the Positive Pole. Heavy Metals, Copper and Zinc. Vasodilating Drugs, Histamine and Mecholyl. Cocain. Epinephrine. Aconitine. Calcium. Applications From the Negative Pole. Chlorine. Iodine. Salicylic Acid. Dangers in Galvanism. Safety Rules.

Historical.—The galvanic current, also described as the direct or constant current, is the basic and also the first known form of electrical current flow. Galvani, professor of anatomy at the University of Bologna in Italy, noticed in 1789 that whenever a spark leapt between the electrodes of an electrical friction machine, a freshly dissected frog's leg which was lying on a metal plate suddenly twitched. But if the leg was hung on an iron grille by a copper hook it also twitched every time it touched the grille. Galvani interpreted this as an evidence that the animal body was a source of electricity and the metals served to discharge it. Soon thereafter another Italian, Volta, proved that electricity arose at the contact of two different metals and caused the muscles of the leg to contract. He constructed the "voltaic pile" from alternate discs of copper and zinc, separated from each other by porous discs made of paper soaked in vinegar. This was the first electric cell ever produced. Volta's discovery was the first means of generating a constant flow of current, but the name galvanism was retained to honor the original discoverer of the phenomenon itself.

The galvanic current came into general therapeutic use at the end of the last century with the construction of wet batteries of fairly large capacity; together with the faradic current it served for many basic observations in the physiology of nerves and muscles. Apostoli's method of treating uterine fibroids by surgical galvanism and Leduc's discovery that it is possible to introduce medicinal substances into the skin through the ionic effects of the galvanic current caused great interest for a few years, but this soon subsided and after 1910 high-frequency currents occupied the center of the electrotherapeutic stage. In recent years improved simplified and inexpensive apparatus for galvanic and low-frequency treatments and the increasing scope of electrophoretic applications restored interest in the therapeutic employment of galvanism. There is unquestionably more room for the extended use of all forms of galvanic treatments.

Physics and Apparatus.—The galvanic or direct (also known as constant) current is an uninterrupted, unidirectional flow of electrons. It may be derived from a variety of sources.

Dry cells or *batteries* are the source of the smoothest flow of current; they have also the advantage that they are easily portable and can be used everywhere. Their essential physics have been presented in Chapter III.

A single dry cell furnishes only a very small amount of current. A $1\frac{1}{2}$-volt dry cell has an output, when working at fullest efficiency, at about 15 amperes. Usually the load is not that heavy and the current depends upon

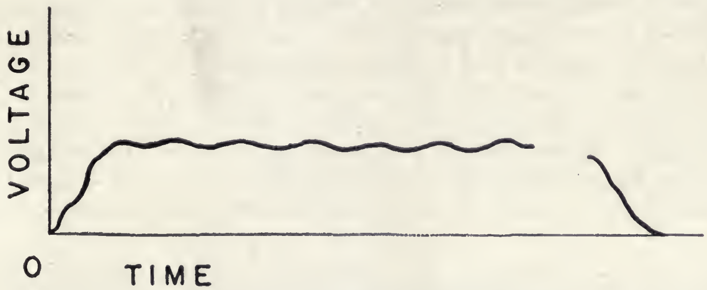

FIG. 98.—Graph of galvanic current from direct current line. Note slight wave in current flow which is due to "commutator ripple" of dynamo. Contrast with even flow from electric cell in Figure 12.

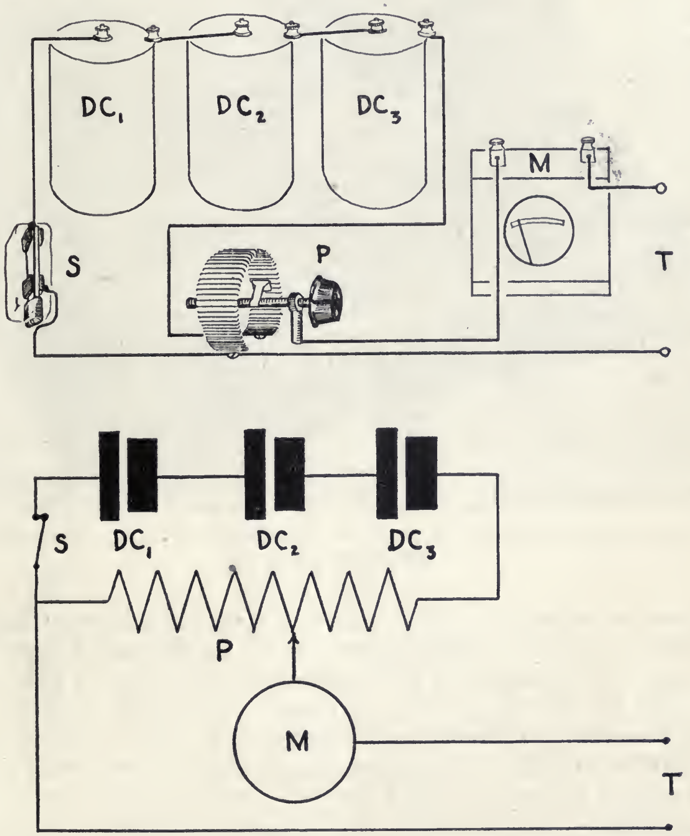

FIG. 99.—Schematic diagram of simple galvanic generator. Upper figure: schematic diagram of a simple galvanic circuit. Lower figure: Equivalent electrical diagram of the above figure. DC_1, DC_2, DC_3, dry cells in series; P, potentiometer; M, milliammeter; T, treatment terminals; S, switch.

the resistance of the circuit. It is more convenient to use the large dry batteries originally designed for radio purposes formerly known as B batteries. They serve as an efficient source of galvanic current. In cases of emergency, several 1½-volt dry cells may be combined into a large battery. The large dry batteries are available in 22½-volt and 45-volt or larger strength. Any electrician should be able to build a homemade galvanic outfit with one of these, placing it in a suitable box and connecting it in series with a rheostat and a plain milliammeter. A rheostat is necessary to control the current strength in the circuit and a meter allows the reading of this amount; the meter also serves to register the eventual decline of the battery. There should be also an indication of the polarity of the apparatus by marking the terminals plainly with + and − signs. Manufacturers furnish, however, also quite reasonably some battery outfits.

Fig. 100.—Galvanic generator with vacuum tube rectification. (Courtesy of the General Electric X-Ray Corp.)

Vacuum or valve-tube rectifiers consist of thermionic tubes (Chapter III) and serve to change an alternating current supply into a fairly smooth direct or galvanic current. These rectifiers consist of a small box or cabinet containing the rectifying tube, a current regulator or rheostat, meter, terminals marked for polarity and pole changing switch. They are portable and relatively inexpensive and are most frequently employed nowadays as a source of galvanism, and of the basic low-frequency currents. (Figs. 100 and 103.)

Metallic rectifiers are so-called bi-metallic junctions of copper and copper oxide arranged at such minimal distance which is comparable with the spacing of the molecules of the two materials. They allow an easy passage of electrons in one direction and stop it in the other and serve as an additional means to change the alternating current into a direct current where the amperage to be passed is of small quantity.

Motor generators consist of a combination of a motor and a dynamo. The motor is either an alternating or direct current motor, according to the supply current, and it rotates the dynamo which furnishes the galvanic current and also usually a number of low-frequency currents. For the

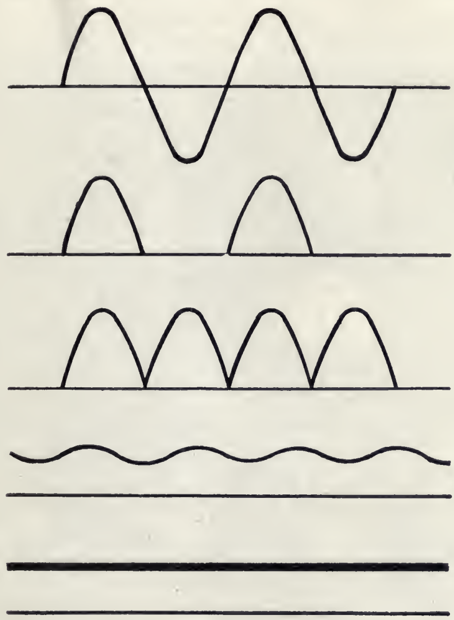

Fig. 101.—Scheme of changing alternating into direct current by vacuum-tube rectification. The stages shown are half-wave rectification, full-wave rectification, partial filtration and finally total filtration.

production of a smooth galvanic current additional condensers and choke coils are incorporated, while rheostats and a motor starting resistance or mechanism, serve to produce some of the low-frequency modifications. These devices make the construction of motor generators both complicated and expensive.

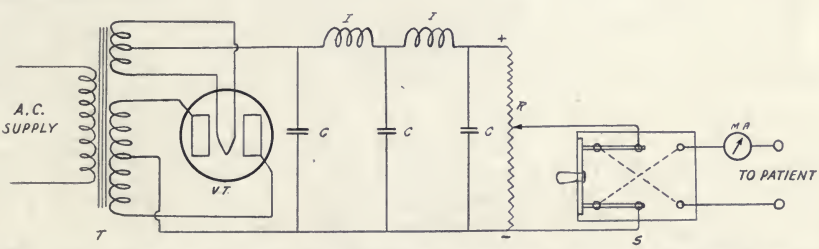

Fig. 102.—Schematic diagram of transforming commercial alternating current into direct (galvanic) current by means of a vacuum (thermionic) tube rectifier. *T* is a transformer connected to the alternating current supply; *VT*, a vacuum tube rectifier; *C*, condensers; *I*, choke coils; *R*, a variable resistance; *S*, reversing switch and *MA*, milliammeter.

Wall plates or *cabinets* are devices using either the direct lighting current, with the interposition of a suitable resistance or the alternating current, with the use of a rectifier tube for the furnishing of a galvanic current. On their panel are mounted the necessary controls, a rheostat to regulate the volume of flow (amperage) and a milliamperemeter to measure it. Some of these outfits also furnish a faradic or other alternating current. Most of them are portable and relatively inexpensive.

Fig. 103.—Portable galvanic and low-frequency generator, furnishing basic four low voltage currents. (Courtesy of Wappler, Inc.)

Polarity.—The galvanic current is the only current applied according to "polarity." All generators of a galvanic current have two terminals or poles, a positive and a negative one. In all forms of galvanic treatments in which an "active" or therapeutically effective electrode is employed, it must be connected to the pole required by the condition treated. Hence the operator must be at times sure which is the positive and which is the negative pole or terminal. Dry cells, rectifier tubes and motor generators are of "fixed" polarity, that is the terminals of the apparatus are marked positive (+) or negative (−); if it is desirable to change their polarity, a suitable switch arrangement always clearly indicates the positive and negative poles. In apparatus using the direct lighting current (D.C.) the polarity of the terminals will change each time the supply plug delivering the current to the apparatus is inserted into the current outlet in a different direction; at times there may be also a change in the direction of the current flow in the main line. In such apparatus it is safer to test each time for correct polarity of the terminals and in case of doubt this should be done with any galvanic apparatus.

Testing for Polarity.—Fasten two conducting cords to the two terminals of a galvanic source and drop the distal tips about 2 inches apart in a flat vessel containing tap water with a pinch of salt added. As soon as a little current is turned on white bubbles appear rapidly and in great numbers around one cord tip. The pole which causes the rapid bubbling is the negative pole (cathode); the bubbles consist of hydrogen gas. After a while a few large bubbles appear slowly at the other cord tip, the positive pole (anode); these bubbles consist of oxygen. This polarity action of the galvanic current is invariably characteristic for each of its poles; if by a "pole-changer" or by different insertion of the line plug the direction of current flow is reversed and the experiment is repeated the rapid bubble formation will take place at the opposite cord tip. Thus the negative pole of a galvanic source can always readily be determined by the quick appearance of many small bubbles (Fig. 104).

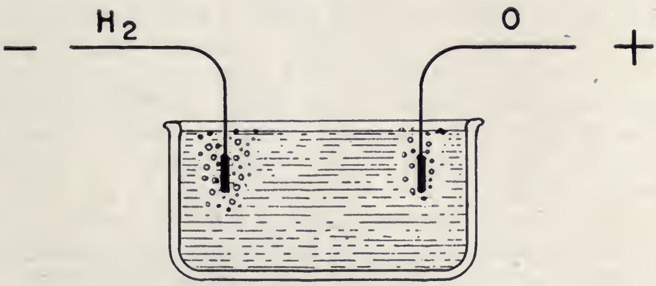

Fig. 104.—Testing for polarity of galvanic generator. With two cord tips placed in a container of salt water many small bubbles (hydrogen gas) appear rapidly around the negative pole and only a few heavier bubbles (oxygen gas) develop slowly around the positive pole.

Another simple test for polarity is the phenolphthalein test: a piece of blotting paper is moistened with a dilute phenolphthalein solution. Touching it with the two cord tips with a slight amount of current flowing, a red dot appears at the negative pole.

EFFECTS OF THE GALVANIC CURRENT UPON THE BODY

While the description of physics of the galvanic current is comparatively simple, the exposition of its physical and physiological effects on the body is a somewhat complicated problem, because of the necessity for explaining not only the action of the current itself, but also that of the two poles. It can be best approached by considering the physical and physiological effects separately.

Physical Effect.—The human body may be considered from the viewpoint of electrotherapy as a bag of skin holding a solution of common salt (NaCl). Figures 18 and 19 in Chapter II show that when the molecules of NaCl dissolve in water they dissociate into sodium ions (Na) bearing a positive charge and chlorine ions (Cl) bearing a negative charge. The flow of a direct current through the salt solution causes these ions to move in a definite direction, the sodium ions migrating toward the negative pole (cathode) and the chlorine ions toward the positive pole (anode), the process known as *ion transfer* or iontophoresis. When the positively charged sodium ions arrive at the negative pole, and the negatively charged chlorine ions at the positive pole, they lose their charge and become free unelectrified atoms; these in turn, cause a secondary chemical reaction in the water and form caustic sodium hydroxide and liberate hydrogen at the negative pole and form caustic hydrochloric acid and liberate oxygen at the positive pole. The *principal physical effect of the ion transfer by the galvanic current is an acid reaction at the positive and an alkaline one at the negative pole;* the intensity of each reaction varies with the strength and relative density of the current at each pole. This acid and alkaline effect may be described as a *polar effect* because it occurs only under the electrodes.

The alkaline and acid reaction of the poles of the galvanic current when increased to sufficient intensity will lead to destruction of tissue by coagulation of protein at the positive pole and by liquefaction of protein at the negative pole. This can be demonstrated by bringing two bare copper wires from the terminals of a galvanic generator to a piece of raw steak, inserting the loose ends into the steak about 2 inches distant from each other. Turning on the current, after awhile a green discoloration appears around the positive pole. This is due to the liberation of the positive copper ions by the repelling effect of the positive pole and the subsequent formation of copper oxychloride in the tissues. The positive wire becomes adherent to the meat due to coagulation of the protein. Around the negative pole a white foam appears (hydrogen gas) and the wire becomes loose, due to the liquefying action of sodium hydroxide on the protein around the wire. This experiment demonstrates that the positive pole of the galvanic current hardens tissue while the negative pole softens it, provided that a current of sufficient intensity is applied and bare metal electrodes are employed. Such intensity is only used in the technique of "surgical" galvanism.

In addition to the polar effect caused by ionic movement, non-dissociated molecules of albumin known as colloids, such as droplets of fat, particles of starch, blood cells, bacteria and other single cells which all have an electrical charge due to the absorption of ions, also move under the influence of a direct current. This movement always occurs towards the negative pole and is therefore known as *cataphoresis*. Finally there occurs also a shifting of the water content of the tissues through a membrane structure with an electrical charge, known as *electroösmosis*. The totality of these phenomena is designated as *electrophoresis*. All this makes it evident that the passage of the galvanic current across or around cell membranes of variable permeability and along fluids of different conductivity and ionic composition presents a complicated biophysical process. The classical potato experiment in Figure 105 is an effective demonstration of the fact that the galvanic current causes ionic movement throughout its path. A hole is scooped in a potato and filled with a dilute solution of potassium iodide two platinum needles are inserted at opposite parts of the potato, connected to a galvanic source and about 3 milliamperes of current is passed through for one-half hour. Bisecting the potato in the level of the needles, a sharply defined dark-blue coloring is found around the positive electrode. This is due to the attraction to the positive pole of the iodine ion which becomes free iodine there and forms starch iodide. No trace of blue is found in the intervening path.

Much speculation has been made as to the possible effects of the change of the electrochemical concentration in the deeper tissues, but there are nowhere definite data or proofs available as to what actually constitutes the *interpolar effect* of the galvanic current. The vague statement as to a general ionic rearrangement conveys little exact meaning. Faraday demonstrated many years ago that electrolytic action takes place solely at the electrodes.

Turrell[19] endeavored to prove that the prolonged passage of the galvanic current along an extremity causes a considerable rise in its temperature. Others, however, are of the opinion that the increase of temperature was due to an increase of the blood supply of the limb consequent to vasodilatation and assert that no heating effect of any therapeutic value can be generated by a current of less than 300 to 500 milliamperes; this amount would greatly exceed physiological toleration.

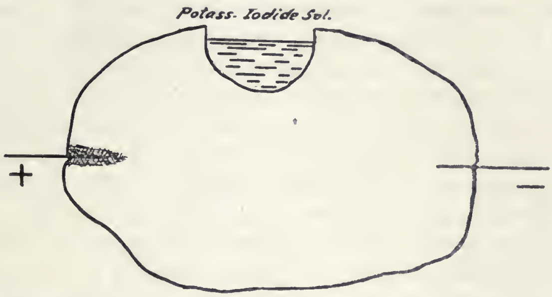

FIG. 105.—Potato experiment. While direct current flows it attracts the iodine anion toward the positive pole and the free iodine there forms blue starch iodine.

Physiological Effect.—The effect of the galvanic current on the skin may be visualized by the following experimental demonstration: Place two pad electrodes well soaked with saline solution upon opposite sides of the knee joint; connecting them to a galvanic current source start a current flow and keep it up at comfortable toleration for twenty minutes. (With electrodes of a size 3 x 3 inches in correct equidistant position, the average patient should tolerate from 6 to 9 milliamperes of current.) When the current begins to flow there will be gentle tingling and pricking under the electrodes; as the resistance of the skin gradually decreases, more current can be tolerated and the pricking sensation changes to a feeling of gentle warmth. As the electrodes are taken off at the end of the treatment, the skin will show a marked redness sharply restricted to the area covered by the electrodes; this color will keep up from ten minutes to one-half hour.

The galvanic skin reaction hyperemia just demonstrated has been analyzed by Freund and Simo[7] as consisting of three phases: A primary period with an active reddening of the skin, which may last several hours; a latent period in which reddening disappears entirely or is only indicated and then a period of renewed hyperemia, designated as a "late reaction" which appears several hours after the primary reaction and may last for several hours. The late reaction can be made to reappear a day later by another stimulus, such as a hot bath; this brings on again an intensive hyperemia on the part previously treated with galvanism. As a rule the redness lasts longer in the area under the influence of the negative pole.

These observations are important not only from the standpoint of immediate physiological response of the skin, but also point to the fact that an electrical application of a relatively short duration may be followed by vasomotor stimulation lasting several hours or days. Proper spacing of the treatments may keep up the stimulative effect and promote a better nutrition not only in the skin, but possibly in the deeper tissues.

Much has been written about an alleged specific pain relieving effect of the positive pole of the galvanic current. The physiological phenomenon of *electrotonus*—the change of irritability produced in motor nerves by the passage of the galvanic current described in Chapter VI had been used by the older electrotherapists as a basis for the statement that the action of the positive pole of the galvanic current is sedative and the action of the negative pole is stimulative on tissues in general. Modern clinicians pointed out that laboratory experiments conducted on the isolated motor nerve with a current of definite intensity are quite different from the action in the human body, where an extremely minute current of unascertainable strength passes along a nerve situated deeply in tissues of low electrical resistance. Kowarschik[13] states that in the treatment of neuralgias, so far as the relief of pain is concerned it makes in most cases no difference whether the anode or cathode was applied over the painful part as long as treatments of sufficient intensity and duration are given. However, in muscle and nerve testing the more irritant effect of the negative pole is unquestionable and it is therefore routinely used as the "stimulating" pole. In clinical use most patients seem to report more discomfort under the negative electrode and nerve irritation seems to be more frequently relieved by connecting the electrode over the affected area to the positive pole. As a newer explanation for the less irritative effect of the positive pole it has been advanced that irritable tissues such as muscles and nerves do not conduct impulses readily in an acid medium, such as produced by the positive pole.

Table 18 sums up the physicochemical and physiological effects of the galvanic poles. Those who wish to carry on some more extensive experimental studies on these effects are referred to the elaborate series of experiments presented in the recent work of Osborne and Holmquest.[17]

TABLE 18.—EFFECTS OF THE GALVANIC POLES

	Physicochemical	Physiological
Positive pole	Acid reaction; repels metals and alkaloids; hardens tissue	Decrease of nerve irritability
Negative pole	Alkaline reaction; repels acids and acid radicals; softens tissue	Increase of nerve irritability
Both poles	Mild heating, electrophoresis	Vasomotor stimulation

TABLE 19.—EFFECTS AND USES OF THE GALVANIC CURRENT

	Polar effect	Interpolar effect	Technique	Principal uses
Medical galvanism	Both poles: vasomotor stimulation; positive pole: acid reaction, coagulation of albumen; negative pole: alkaline reaction; liquefaction of albumen	Mild heat; increase of circulation	Moist pad electrodes preferably even size	Selected cases of acute and chronic inflammatory conditions, especially fibrotic thickening, circulatory disturbances
Electrolysis (surgical galvanism)	Positive pole: acid caustic, tissue constriction; negative pole: alkaline caustic, tissue liquefaction	Negligible	Active electrode: pointed metal, dispersive electrode: large pad	Removal of superfluous hair, warts and moles; treatment of dilated blood-vessels
Ion transfer (iontophoresis)	Positive pole for copper, zinc, quinine ions and alkaloids; negative pole for chlorine, iodine, salic. acid ions	Mild heat; increase of circulation	Solution or metal containing ions serves as active electrode	Chlorine ions to soften scars; zinc ions in otitis media; copper ions in cervicitis and vasodilating drugs in arthritis

Therapeutic Forms.—For therapeutic purposes, there are three forms of the employment of the galvanic current: (1) *medical galvanism,* the administration of the "straight" galvanic current within physiological toleration; (2) *electrolysis* or surgical galvanism, the electrochemical destruction of tissues by the galvanic current; (3) *ion transfer,* electrophoresis or medical ionization, the application of the galvanic current within physiological toleration to effect the passage of medicinal ions through the skin or mucous membrane.

MEDICAL GALVANISM

Clinical Effects.—The galvanic current applied within physiological toleration to a part of the body surface causes vasomotor stimulation of the skin and increased circulation and nutrition of the parts in the path of the current. The generally accepted explanation of the clinical effect is that the improvement of circulation speeds up the resolution of inflammatory products, reflex stimulation or relief of pressure relieves pain; galvanic treatments of sufficient extent or intensity (galvanic baths) may also influence general circulation and metabolism.

Indications.—Medical galvanism has proven clinically useful in a number of acute and chronic inflammatory conditions such as: (1) selected cases of traumatism, contusions, sprains, myositis, both in the acute and chronic stage; (2) selected cases of arthritis and rheumatic conditions, neuritis and neuralgia, mostly in the chronic stage. In the management of some circulatory disturbances of the brain, such as in after-treatment of selected cases of cerebral hemorrhage, medical galvanism often serves as a useful adjunct.

In spite of its time-proven effectiveness, the "straight" galvanic current is still too little employed in the United States at present, compared to the increasing popularity of its uses for electrophoresis. It should be remembered as a useful alternate for diathermy treatments, especially in heat sensitive patients.

General Technique.—In medical galvanism the area to be treated is covered by moist-pad electrodes corresponding with its size. Transverse application of electrodes of equal size is preferable. The interposition of a moist pad between the plate and the skin is necessary for overcoming skin resistance, for protection of the skin by absorbing the caustic metallic compounds formed on the surface of the metal plate and for maintaining perfect contact. The smooth flow of current depends on the thorough moistening and good apposition of the pads and on their safe retention. Moistening of electrodes is best done by holding them first under running warm water; after they are thoroughly soaked they should be placed in a flat vessel containing a warm saline solution. This brings the pads to the required temperature, and after gently squeezing out the excess water, they are placed over the parts to be treated. They are held by an elastic bandage, preferably a rubber one.

Patients sensitive to cold and to moisture will complain if the electrodes are not applied at a comfortable temperature or are too wet, causing oozing all over the body and clothing. It is helpful to cover the pads with a bath towel or oiled silk during treatment. Insufficient moistening of the pads will cause their drying out during treatment and may give rise to imperfect conduction. If the patient complains of unpleasant burning at any time during treatment, and the amount of current does not seem excessive, the first thought is insufficient moistening of the pads causing undue current density in one spot. The remedy is to shut off the current, take off the pads, remoisten them and reapply them carefully.

No special attention to polarity has to be paid when "straight" galvanism is applied with electrodes of equal size, therefore it makes little difference to which pole each electrode is being attached. In case however there is a more sensitive area on one side of a joint, it may be more comfortable to connect it to the positive pole because it is less irritating. On the same principle it is also advantageous to reverse the polarity of the current during the second half of each treatment. This must be done by carefully returning the control to zero, turning the reversing switch or changing the position of the cord tips in the terminals and then gradually advance the control again to the same comfortable point of toleration.

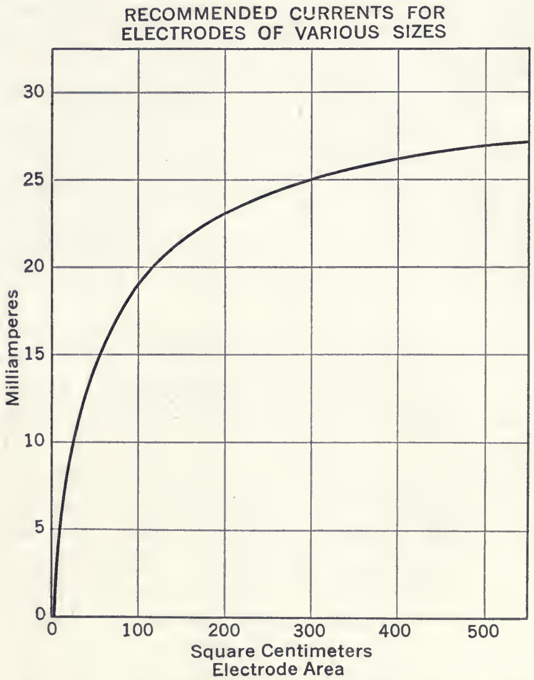

Fig. 106.—Recommended current values with electrodes of various sizes for therapeutic iontophoresis. (Molitor and Fernandez.)

Dosage and Length of Application.—Current strength must be always within comfortable toleration. As an average, the normal skin tolerates about ½ to 1 milliampere of galvanic current per square inch of electrode surface. The size of electrodes furnishes, therefore, a guide as to the expected current toleration. The smaller the electrodes, the greater the current density and the less current can be applied. If the electrodes are placed on the same body surface the question of edge effect must be taken into consideration.

As the treatment goes on, skin resistance decreases and the meter reading shows a slight increase. At the same time the sensitiveness of superficial nerve also decreases and the rheostat can now be further advanced because of better toleration of the current. With electrodes of suitable size, from 10 to 20 milliamperes of current may be used in facial neuralgia; from 15 to 30 milliamperes in sciatic neuritis and about the same amount in abdominal conditions. The current values for electrodes of various sizes have been studied by Molitor and Fernandez[16] and their findings are shown in Figure 106.

As a general rule, galvanic treatments should start with fifteen- or twenty-minute periods and extend up to thirty or forty minutes. Newer investigators emphasize that the alleged ineffectiveness of galvanic treatments which led to their gradual abandonment was mainly caused by too little current being applied for too short a period. The seeming superiority of ionic medication in joint conditions has been attributed more to treatments of sufficient length than to action of the specific drug employed. Treatments may be repeated daily or every other day.

Patients should never be allowed to get off the table and go outdoors with their underwear or other clothing wet from a galvanic treatment.

Regional Technique.—Galvanic treatment of the *brain* has been in use under the designation of cerebral galvanism for many years. In its technique two pad electrodes, about 4 inches long and 2½ inches wide, are moulded and retained in firm apposition to the forehead and the nape of the neck. A few turns of an elastic bandage will secure the frontal electrode; the occipital electrode may be held by the head resting on a suitable pillow or should be also secured by bandaging, especially if the patient is restless and likely to attempt moving during treatment. One should never apply cerebral treatment to a sitting patient. The frontal electrode is connected to the negative pole and the occipital one to the positive pole. Bitemporal (from side to side) application of galvanism causes dizziness, the head falling over toward the side of the positive pole. The current should be turned on very gradually, 1 milliampere at the start, and be increased very slowly up to 2 to 5 milliamperes. A smooth galvanic current supply is important and with careful avoidance of sudden current interruption or fluctuation the technique is perfectly safe and easily tolerated. At the end of treatment the current must be turned off very gradually.

Cerebral galvanism may be employed in treatment of some of the after effects of hemiplegia (Chapter XXVII) and also in nervous headaches and mild neuroses.

For treatment of the *face* (in facial paralysis or trifacial neuralgia) a crescent-shaped electrode is applied over the affected side and connected to the positive pole. The large dispersive electrode is placed under the chest or back. From 5 to 15 milliamperes of current may be applied. For treating the thyroid gland a suitably shaped and sized pad electrode is placed across the gland and a larger dispersive one is applied under the upper back.

For treating the *upper extremity* (in brachial neuritis) an electrode about 3 x 4 inches is applied across the neck corresponding with the brachial plexus and another electrode 2 x 5 inches over the flexor surface of the forearm (longitudinal technique). Immersing the hand and part of the forearm in a water-bath appears to be more effective. Another method of treatment is to wrap up the entire area with asbestos fabric paper or a thin towel moistened with saline solution (placing a metal electrode on top) and use a large dispersive pad under the back.

For treating the *lower extremity* (in sciatica) the same methods as for the upper extremity may be employed. In addition the transverse technique may be also applied, by making up two long electrodes from well moistened Turkish toweling for the anterior and posterior surface of the leg and thigh, and applying metal plates over these (the towel connected to the positive pole will show metal stains). For treatment of the *knee* (in chronic arthritis) electrodes 3 x 3 inches in size are applied over either side of the joint or moistened asbestos fabric paper may be wrapped around the joint and a dispersive electrode placed under the gluteal region.

The Galvanic Bath.—The galvanic current may be conveniently and efficiently applied to the whole body or to one or more extremities by means of hydroelectric baths. Such baths have been used abroad as part of the established physical therapeutic armamentarium for over half a century, but until very recently have been comparatively neglected in the United States. They differ from the usual method of applying the galvanic current by the very much enlarged contact surface through the medium of the water and by the possibility of employing much larger amounts of current flow.

As a source of current supply for the full galvanic bath, motor generators are generally preferable to wall-plates or other not ground-free sources. A distinct danger in full galvanic baths, which has led to a number of fatal accidents, is the possibility of the patient touching grounded object in the bathtub or outside of it and receiving an electrical shock through the free ground current. (See Chapter XV.) To prevent this risk, bathtubs must be insulated, metal fittings and taps within the reach of patients avoided and patients emphatically warned against touching metallic objects inside or outside the bath. With especially constructed modern hydroelectric apparatus treatments may be administered in perfect safety and the patient may even touch any grounded object. For general treatment the author[12] has in recent years employed a two circuit apparatus which is ground free and enables a variety of combination in technique, and which also allows additional stimulation by the use of a rippled or pulsating direct current.

The electrodes for galvanic baths consist of carbon plates held in perforated wood which enables the current to pass but prevents the plate from touching the patient's skin. As a rule five electrodes are used for the full bath, one on each side of the bathtub, one on the foot end, one in the center and one large back electrode equipped with a head rest. The tub is filled with tap water at a temperature comfortable to the patient (anywhere between 92° and 100° F.). It is well known that a small amount of salt decreases the resistance of the water and allows more milliamperage to pass at a lower voltage. In recent years adding of a tannin bark solution became a standard procedure in hydroelectric baths on the ground that it reduces the resistance of the water to a certain suitable degree and decreases skin tingling; by its dark color it also helps to avoid exposure of the uncovered body and saves the use of linen sheets or a rubber sheet covering on the patient. The usual technique is to establish one longitudinal circuit to one side of the apparatus and a transverse circuit to the other side. The polarity of the electrodes and the direction of current flow can be regulated according to a number of schemes. Since all electrodes are movable, it is possible to concentrate the current flow to any desired part and vary the amount of local or general stimulation. From 60 to 100 or even more milliamperes may be used on each of the two circuits. The duration of general bath treatment should be from fifteen to thirty minutes. Itching occurs in a number of instances after either local or general treatment. Application of fine talcum powder or of a calamine lotion or ointment usually promptly relieves this.

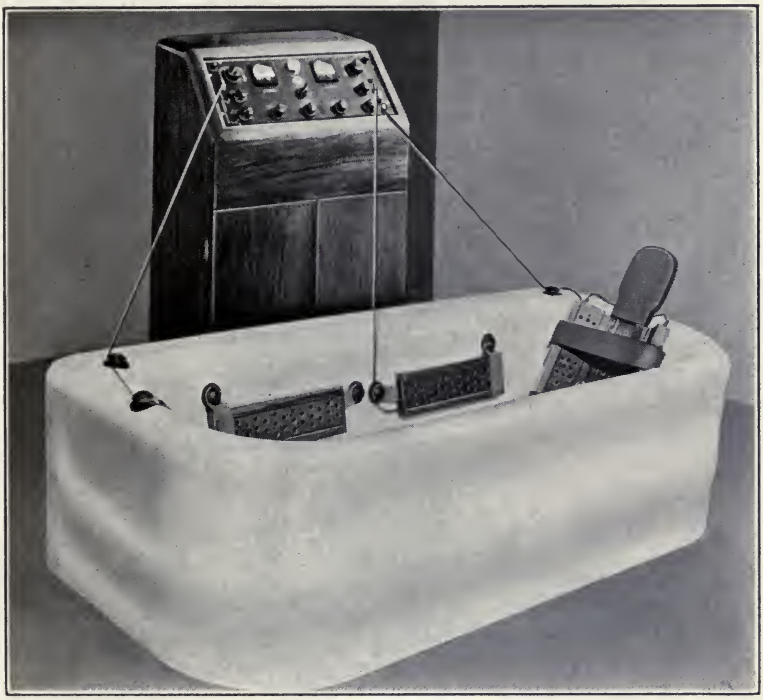

Fig. 107.—Electrogalvanic bath. (Courtesy of Teca Corp.)

The factors governing the mode of action of hydroelectric baths are the form of current and the technique of its application, the temperature and hydrostatic action of the water and additional stimulation when chemical ingredients are added. It seems established that only about one-third of the current employed flows through the body, but even this amount is larger than in any other form of galvanic or low-frequency treatment, and it is evenly and relatively painlessly distributed.

The electrochemical effects of the galvanic current employed in the bath bring about chiefly a stimulation of the skin and of the nervous system. The additional use of the pulsating or rippled current adds to the stimulation. According to Wedekind[20] and others the filling of the peripheral blood-vessels is normally decreased and the blood-pressure generally falls, especially in cases of hypertension. Electrocardiographic tests as well as studies of the blood picture did not show consistent results; neither did metabolic tests prove a conclusive effect. Clinically there appears to be a definite influence in the general well being and appetite of patients. The buoyancy of the water is a factor in the general comfort and increased mobility of painful or weak parts in the hydroelectric bath. As the water is usually tepid, the thermal effect is generally negligible. In local treatments, the action of the galvanic current as a stimulant of local metabolism and as a counterirritant is well known and explains most of the clinical results.

Local galvanic baths can also be administered with the same apparatus which is used for the full bath treatment. It is important that the apparatus used for local treatments produces a very smooth current since it is not possible otherwise to use the large amount of current which should be applied to make the treatment effective. It is also of advantage to have a pulsating current available. The apparatus is connected to one, two or more water filled tanks into which the extremities are immersed. Not only

Fig. 108.—Four-cell galvanic bath (Schnee type). Galvanic generator not shown. (Courtesy of the Medical Supply Association, Ltd., London.)

the galvanic current but also all other forms of low-frequency currents may be administered through the medium of a hydroelectric bath. Abroad the hydroelectric Schnee-bath is a well known apparatus. An improved American tank unit has the advantages over the Schnee-bath that the two circuits of this power unit allow a separate regulation of current flow between two extremities, as well as the treatment of two patients at the same time. In local galvanic bath treatments the simplest procedure is to place two extremities in one tank each, thus having the area to be treated between one positive and one negative electrode. The amount of current comfortably tolerable to the patient—between 20 and 50 milliamperes—is gradually turned on. This is several times the amount which can be safely applied with ordinary moist pad electrodes. In the routine treatment, after ten to fifteen minutes the direction of the current flow is reversed by reducing the current to zero, turning the pole-changing switch and then advancing the current again and allowing it to flow for another ten to fifteen minutes. Stimulative effect may be exerted by advancing the pulsating current control switch and admitting a tolerable amount of rippled current. A combination of tank treatments with ordinary moist pad electrodes is also possible, as for instance application of a moist pad over the shoulder and holding one or both forearms in one or respectively two tanks with the polarity suitably chosen (Fig. 247).

If an extremity is placed in one tank between two electrodes (positive and negative) between 100 and 150 milliamperes can be used. In this arrangement only the part of the extremity between the two electrodes can be treated.

Clinical Uses.—Galvanic baths have been recommended abroad as aids to general medical treatment in mild general arteriosclerosis and in many rheumatic and nervous ailments. In the author's recent experience best results were seen from full baths in selected early cases of multiple joint involvement, both rheumatoid and osteo-arthritic. The relief from pain and the improvement of function was striking in some of the cases, and the general roborative effect was marked in most cases. Satisfactory responses were also seen in several cases of polyneuritis. Behrend[3] reports striking results in a series of cases with a pain syndrome of true neuralgia which resisted the ordinary conservative methods of treatment. Nervous exhaustion in the war disabled also has been reported responding satisfactorily.

Local galvanic baths may be employed in all cases where galvanic treatment along the extremities is indicated such as vasomotor disturbances, paresthesias, neuralgias, and also selected cases of peripheral nerve injuries and other traumatism.

ELECTROLYSIS OR SURGICAL GALVANISM

The term electrolysis denotes in the technical world the decomposition of a chemical compound by the ionizing effect of a direct current. In medicine it has become identified with well controlled tissue destruction by the caustic effects of the galvanic current, applied through a fine needle as the "active" electrode while a fairly large moist pad serves as a "dispersive" electrode to complete the circuit. The needle electrode is usually made of platinum—iridium, fixed in a suitable holder; it is connected to the negative pole for tissue liquefaction (alkaline caustic effect) and to the positive pole for tissue coagulation (acid caustic effect). The chief advantage of surgical galvanism is that the amount of destruction, depending on the strength and duration of the current flow, is always under control and well localized, and the cosmetic effects are very satisfactory because of the minimum of scarring.

Removal of Superfluous Hair.—The principle in treating superfluous hair (hypertrichosis) by electrolysis is to apply current of sufficient strength from the negative pole to destroy the follicular lining, the papilla and hair root. If properly carried out the treatment is followed by a smooth and almost invisible scar and the total disappearance of the unwanted hair. (For details see Chapter on dermatological conditions.)

Skin Blemishes.—The mild and well regulable caustic effect of the galvanic current has been employed for many years successfully for the destruction of minor blemishes and benign tumors of the skin. Among these are telangiectasis, moles containing hair, rosacea, spider nevus, angioma of small size, filiform and flat warts, xanthelasma, adenoma sebaceum (Lewis[15]). Every dermatologist warns against applying the method when dealing with any potentially dangerous lesions of the skin, such as black pigmented moles and melanoma. In such cases, death of a patient may result from subsequent metastases.

Technique.—A moist pad electrode placed suitably or a moist sponge held by the patient serves as a dispersive electrode and is connected to the positive pole. The active electrode is a needle held in a needle holder; it is connected to the negative pole and inserted across the base of the growth transfixing it parallel with the skin surface. For the usual small growth a current of 1 to 2 milliamperes is turned on and then slightly increased until in a minute or so a whitish-gray discoloration along the needle appears. The needle is then withdrawn and employed at right angles to the first insertion and this process is repeated until the entire growth appears discolored and swollen.

Experience is necessary to judge accurately the amount of current to be employed. The needle should never dip down into the mole; for a perfect result parallel insertions of the needle are essential.

At the end of the treatment the growth is either covered with a small aseptic dressing or may be left uncovered. The devitalized parts subsequently dry off and separate spontaneously within a few days; a small dry scab covers the surface underneath, and in the course of a few more days this area becomes epithelialized. The cosmetic result is usually satisfactory.

In moles containing hairs the latter must be always removed first, before anything is done to treat the mole. These hairs are more difficult to remove than other hairs, because their length is very variable and the course of their follicle is usually tortuous. A fairly strong current may be employed because it will help to shrink the mole. Small hairy moles containing many hairs often entirely disappear after the hairs have been removed. In larger moles, after the hairs have been treated, either electrolysis or electrodesiccation should be employed to finish the work. Hairy moles are never malignant.

Filiform and flat warts are treated by a technique similar to non-hairy moles; they should be held by a small forceps and their base transfixed when tense. Only a minimum of current should be employed.

Hemorrhoids.—Obliteration of hemorrhoids by surgical galvanism has been variously recommended. (See Chapter on proctologic conditions.)

Strictures.—Galvanism from the negative pole in gradually increasing strength has been successfully employed in strictures of the male urethra (Chapter XXXI), stenosis of the cervix (Chapter XXX) and also in bronchial strictures (Kernan and Baker[10]).

Galvanic Acupuncture.—Galvanic acupuncture is a method for relief of pain in stubborn cases of chronic neuritis by mild surgical galvanism. It is not at all practiced in the United States, but favorably spoken of in England, where it was originated by Davies. The procedure, as described by Cumberbatch,[5] consists of first locating the hyperalgesic areas by an active disc electrode, $\frac{1}{4}$ inch in diameter, connected to a source of faradic or sinusoidal current. Just enough current is turned on to elicit a painless sensation of pins and needles in the normal skin. The spots in which the same amount of current causes severe pain are treated in succession on different days as follows: A few drops of a 1 per cent novocaine solution are injected under the skin in the center of each spot. A needle electrode of special design, connected to the negative pole of a source of galvanic current, is passed through the opening made by the syringe needle. A current of 1 to 2 milliamperes is passed and the needle is made to explore the skin and fascia until a location is found where the neuritic pain complained of is most intense. The electrode is kept for at least five minutes in this situation, and the current may be increased at 5 milliamperes.

The rationale of this treatment is explained by a counterirritation of a nerve twig along which the pain is referred to the surface, and it is claimed that patients can be made free from pain after all painful spots have been treated.

ION TRANSFER OR IONTOPHORESIS

Physicochemical Considerations.—*Ionization* in a wider sense refers to the breaking up of any substance, gaseous, solid or fluid, into its component ions by an outside force, usually an electrical current. Molecules of acids, bases or salts dissolved in liquid divide into positively and negatively charged ions even without the flow of any current. As a constant or galvanic current passes through such a solution, it causes a migration of the ions in a definite direction; those with a positive charge are attracted to the negative pole and those with a negative charge to the positive pole. This process is known as ion transfer or *iontophoresis*.

The galvanic current not only affects the transfer of ions contained in the tissues, but also may be employed to break up medicinal substances at its poles by opposite electrochemical affinities and to drive them into the human body through the skin and the mucous membranes. Ions with a positive charge—metals (zinc, copper, etc.) and alkaloids may be introduced into the tissues from the positive pole, while ions with a negative charge—iodine, chlorine, acid radicals are introduced into the tissues from the negative pole. Leduc,[14] the chief originator of ionic "medication" proved by classical animal experiments that the introduction of drugs in solution into the body was directly due to the flow of current and not to simple absorption by the skin from the wet pad soaked in the drug.

Leduc's Experiments.—A pad of gauze moistened with a solution of strychnine sulphate was applied to the internal surface of a rabbit's ear and held down by a small metal plate. Even if the pad was thus left in contact for a long time nothing happened. If, however, the pad was made part of a galvanic circuit and connected to the positive pole, while an indifferent pad electrode moistened with water or salt solution placed against any other part of the rabbit's body was connected to the negative pole, upon starting the current flow, in a few minutes the rabbit was seized with convulsions and died with the symptoms of strychnine poisoning. Leduc[14] repeated the same experiment with two rabbits and two drugs as illustrated and described in Figure 109.

Newer investigations particularly those of Rein have demonstrated that besides iontophoresis, movement of electrical ions, *electroösmosis*, or of shifting of the water content through the pores of the skin under the influence of a galvanic current plays an equally important rôle in the introduction of electrically charged colloidal substances.

Penetration of Ions.—It has been shown that as rule medicinal ions cannot be made to migrate far below the surface of the skin and mucous membranes; consequently ionic medication is essentially a local or intradermic form of treatment and systemic effects are an exception. This conclusion is based on the following established facts:

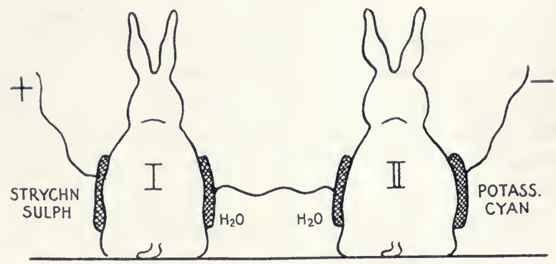

Fig. 109.—Leduc's classic experiment. Two rabbits are placed in series in the same galvanic circuit, so that the current has to pass through both. The current enters into the first rabbit by a positive electrode soaked in strychnine sulphate, leaves by a negative electrode soaked with plain water, enters the second rabbit by an anode soaked with water and leaves by a cathode of potassium cyanide. When a current of 40 to 50 milliamperes is turned on, the first rabbit is seized by tetanic convulsions, due to introduction of the strychnine ion, while the second rabbit dies rapidly with symptoms of cyanide poisoning. If the two animals are replaced by new ones and the flow is reversed, the animals are not harmed, because now the strychnine ion is not repelled by the positive pole and the cyanide not repelled by the negative pole.

1. Different ions move at fixed rates of speed which increase with the voltage and diminish with the distance in the electrolyte through which they travel. The displacement of the ions being the electric current itself, the traveling speed of the fastest positive ions, the hydrogen ions, must be considered identical with that of the current. The fastest negative ion is the hydroxyl radical, and as this and the hydrogen ion are present in immense number in the body fluids, the greater part of any electrical current is carried by them. The other ions being much less speedy and less numerous, they do not transport the electric current at all. This reason alone explains why medicinal ions are introduced into the tissues only in a very small quantity (Turrell[19]).

2. When a medicinal ion enters the body it is almost immediately deprived of its charge by the electrolyte salts of the body fluid, the blood stream and lymph. In addition ions of the heavy metals rapidly unite with the tissue proteins, forming insoluble compounds.

Data are now available on the actual depth of migration of ions under the influence of the current. Rein introduced methylene blue in animal experiments with dogs and rabbits and found deep blue staining of the stratum corneum, dark blue of the stratum Malpighii, with the stained hair follicles reaching into the subcutaneous fat tissue. Harpuder[8] confirmed this on animals but with biopsy material of the human skin there resulted only a staining of the epithelial skin, most intensive on hair follicles and oil glands, with no demonstrable stain at the muscle fascia.

It is the consensus of investigators that the introduction of certain drugs by electrophoresis increases their pharmacodynamic effects and thereby their therapeutic result. With some drugs ionization results in a deposit in the layers of the skin with slow absorption and sustained clinical effect.

Generally speaking, more intense penetration occurs from the positive pole. Ions introduced by the positive pole are the heavy metals—copper, zinc, magnesium—alkaloids, morphine, cocain, histamine, and cholin derivatives. The negative pole will introduce salicylates, iodides and bromides.

Clinical Uses of Ion Transfer.—The introduction of electrically charged particles of certain drugs or of the salts of heavy metals by the polarity effects of the galvanic current finds a steadily increasing employment in all departments of medicine. The object of these electrophoretic applications is either local stimulation of the function of tissues—a form of counter-irritation—or a mild local caustic effect, the precipitation of tissue proteins and the resulting elimination of diseased tissue.

The mode of action and clinical uses of the various substances employed for electrophoretic applications and also some of the special techniques will be described in this chapter. The critique of the methods and the detailed technique relative to the most frequently treated conditions will be presented in the chapters dealing with special conditions.

In *skin conditions,* fungus infections and other forms of chronic dermatitis of hand and feet have been successfully treated by copper as well as by silver nitrate ion transfer; scleroderma and keloids by mecholyl or potassium iodide ion transfer; light superficial scars by chlorine ion transfer; in varicose ulcers spectacular results have been achieved by mecholyl ion transfer.

In *gynecology,* chronic endocervicitis and cervical erosions have been for many years treated with copper ion transfer; recently, mecholyl ion transfer has been used in pelvic inflammation (Chapter on gynecologic conditions).

In *ear, nose and throat conditions,* zinc ion transfer has been used for many years in the treatment of chronic otorrhea, and in recent years, in chronic and vasomotor rhinitis, and also in trachoma. (Chapter on nose and throat conditions.)

In *arthritis and rheumatoid conditions,* as well as in traumatic conditions of soft tissues, both mecholyl and histamine ion transfer have found widespread application in recent years. (Chapter XXVII.)

In *medical conditions,* histamine ion transfer has been employed for the relief of migraine and headache, epinephrine for severe asthma, aconitine and of nupercaine for muscular spasm. Calcium ion transfer by cerebral galvanism has been recommended for the chronic stage of hemiplegia.

In *peripheral vascular disease,* mecholyl ion transfer has been found useful in producing prolonged local vasodilatation.

General Technique.—A galvanic current generator in good working order is essential; its two terminals must be marked for their proper polarity. For application through the skin the *active* electrode conveying the medicinal solution should be made of absorbent material of sufficient thickness or consist of a medicated water bath. The strength of all solutions should be 1 per cent or less as no advantage is gained by making it stronger. Gauze of a thickness of ½ inch (about 16 layers) is best, but cellucotton, felt or folded hand towels of the same thickness may serve for pads. For the introduction of vasodilating drugs special asbestos fabric paper is available. The active electrode is soaked with the solution at a temperature of comfortable warmth and is laid on with firm contact over the area to be treated. A metal plate of somewhat smaller size or a metal foil is placed upon the pad, being very careful that no metal edge anywhere touches the skin; even a minute, direct contact between the metal and the skin may lead to a chemical burn. (Fig. 113.)

For a *dispersive* electrode, a pad electrode of larger size than the active electrode is soaked in tap water or saline solution and is placed in firm contact with a convenient part of the body surface. Suitable metal clips or other fastenings serve to secure the conducting cords to the metal plates of the active and dispersive electrodes; one must strictly avoid possible contact to the skin of this clip; if necessary use a small piece of rubber sheeting. The conducting cords must be securely attached to the proper terminals of the galvanic apparatus. A foot or arm bath may also be used as a dispersive electrode in all forms of treatment.

For treatment of mucous surfaces—the cervix, nasal cavity or the inner ear—a metallic electrode, solution or packing containing the ions is placed in direct contact with the walls of the cavity and serves as the active electrode.

The *strength* of the current used in iontophoresis should be generally the maximum that can be tolerated with comfort. Figure 106 shows the current strength in relation to the size of the active electrode as in the curve worked out by Molitor and Fernandez. The *length* of treatment varies with the condition and the potency of the drug; from five minutes in histamine ion transfer for counterirritation to one hour in chlorine ion transfer for softening scars.

The *danger of burns* is always present in electrophoretic applications and can be avoided only by the rigid observance of the general rules of treatment described at the end of this chapter.

If treatment pads are to be used again they must be thoroughly cleaned and rinsed after each treatment in order to get rid of the secondary chemical products near the metal plate. The asbestos fabric paper can be employed two or three times and is simply remoistened each time with the same stock solution.

A. Applications From the Positive Pole

Heavy Metals.—Copper and Zinc.—The action of the ions of the heavy metals differs from the action of the medicinal ions; instead of a soluble molecule which is absorbed by the tissues, the free ions of copper and zinc produce an insoluble protein precipitate. The result is a local germicidal effect, due to the antiseptic properties of nascent ions and also a coagulation of tissue protein in proportion to the strength and the flow of the current from the positive pole. Following the application a slow separation of detritus takes place from the thin or heavy slough and later healthy new granulation tissue is formed. In contrast to superficial action of the usual caustics, copper and zinc ion transfer extend deeper into the recesses of the mucous membrane. Accordingly, these caustic ions have been found clinically effective for treatment of infected granulation tissue, for mild cauterization of mucous membranes, for stimulation of indolent ulcers and for sterilization of infected sinuses.

Copper is employed in the treatment of endocervicitis through a plain copper electrode (Chapter XXX), and also as a solution of copper sulphate for the treatment of sluggish wounds or ulcers, and also in fungus infections of the skin (Chapter XXXIII).

Zinc is the most antiseptic of the caustic ions and is being employed in the form of zinc sulphate or zinc chloride solution for treatment of infected sinuses, indolent ulcers, selected forms of chronic otitis media, and some inflammatory eye conditions. For details of treatment of otorrhea and of hay fever and other allergic conditions, see Chapter XXXIV.

Before treating any cavity or sinus with zinc ion transfer it must be first thoroughly syringed out by a solution of 1 per cent zinc sulphate in order to remove all foreign material, pus, débris, which prevent the thorough contact of the ionizing substance with the infected surface. A fresh supply of zinc solution is then injected, a zinc rod or wire inserted and kept *in situ* by suitable insulation. (Fig. 337.) This electrode is connected to the positive pole. A dispersive moist pad electrode is placed in a suitable location and connected to the negative pole. Current of comfortable toleration is employed and kept up for ten minutes to one-half hour, according to the pathological changes present. A grayish-white discoloration of the tissues appears, the extent of which enables the operator to gauge the effectiveness of the treatment. Treatment may be repeated in a week or two.

Vasodilating Drugs.—Interest in the use of vasodilating drugs for improving the peripheral circulation in rheumatic and other conditions led to the discovery that when administered by ionization these drugs are readily absorbed and exert well controlled local as well as general effects. The vasomotor stimulation by the galvanic current itself also adds to the effect.

Histamine.—Histamine is a substance which is regularly formed in the skin as a result of thermal, mechanical or chemical irritation as shown by Lewis and Grant. It causes dilatation of the capillary blood-vessels and if the injury or irritation is severe enough, capillary permeability is so much increased that formation of wheals occurs. Histamine is introduced into the skin by the positive pole of the galvanic current from a solution or ointment applied to the skin. A few minutes application of a weak solution will result in intense hyperemia, formation of wheals and large patches of urticaria. This local reaction probably extends to some depth. Skin temperature measurements show a rise of 3° to 5° F. The effects of local vasodilatation persist from one to four hours and the skin returns to normal appearance.

The vasodilating and counterirritant effect of histamine ion transfer has been found effective in treatment of traumatic and rheumatic affections of superficial soft tissues, such as myositis, fibrositis, sprains, neuritis. Deutsch[6] who introduced histamine treatment attributed the favorable results to a nervous reflex effect on muscle pain and spasm without an anesthetic effect in the ordinary sense. He emphasizes that histamine will only relieve pain which is connected with local tenderness or limitation of motion. Favorable reports have been given of cerebral histamine ion transfer for treatment of migraine and headache and for post traumatic conditions. Older patients often report a feeling of well-being after local histamine treatment; this may be attributable to a slight systemic effect, causing a fall of blood-pressure.

With the usual technique of local treatment there are no general effects of histamine administration; prolonged or excessive administration however may result in increase of pulse and metabolic rate, a fall of blood pressure, a sensation of flushing and heat around the head and neck and severe headache. Patients with a history of bronchial asthma should not receive treatment by any vasodilating to avoid any possible untoward systemic effects.

In the technique of histamine ion transfer one may employ a 1 to 1000 solution of histamine dihydrochloride or histamine acid phosphate or a 1 per cent histamine ointment. For applying the solution several thicknesses of gauze or flannel are saturated with it; one may also use asbestos fabric paper or several layers of filter paper; the resulting "active" pad electrode is lightly wrung out and placed over the area to be treated; over this pad is laid a malleable metal electrode of slightly smaller size (to prevent skin contact of the metal) or a ready made moist pad electrode of suitable size. For treatment with an ointment one may employ the ready made "imadyl" unction, rubbing a small amount of it gently into the area, after it has been warmed for ten minutes by a heat lamp or warm towels. Wiping off the excess ointment the area is then covered with a pad electrode as already described. The histamine bearing electrode must always be connected to the positive pole, while the standard type of dispersive electrode is connected to the negative pole. For the first treatment it is advisable to use only a current strength of 5 milliamperes for five minutes; this can be increased subsequently up to 10 milliamperes and ten minutes, according to the extent of reaction obtained. Treatments can be given daily or every other day (Hummon[9]).

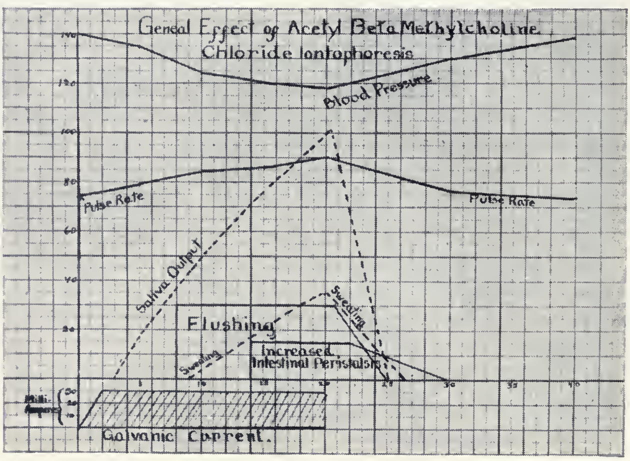

FIG. 110.—Curves showing systemic effects of iontophoresis by acetyl-beta-methylcholine chloride. (J. Kovacs.[11])

Mecholyl.—Acetylcholine is a substance of great physiologic potency; as a parasympathetic stimulant it causes dilatation of peripheral blood-vessels, slowing of the heart, falling of blood-pressure, constriction of the pupils, increase of intestinal tone and peristalsis, stimulation of the detrusor muscle of the bladder and increase in intestinal tone and peristalsis. It is a pharmacologic antagonist to epinephrine. *Mecholyl* (acetyl-beta-methylcholine chloride) is a derivative of acetylcholine, which can be administered by ion transfer through the unbroken skin and exerts a well controllable local action in peripheral vascular conditions and some types of arthritis.

The local effects of mecholyl ion transfer observable immediately after application are as follows: Marked redness of the skin, sharply localized to the area of application, and remaining for one and a half to two hours; "goose flesh," due to contraction of the erector muscles of the hair follicles, remaining for ten to thirty minutes; perspiration of the treated skin area, continuing for eight to ten hours, probably due to direct action on the skin glands; increase of the skin temperature in cases where a spasm of the peripheral blood supply was present; increased salivation when treatment was applied in the region of the salivary glands; and finally a warm feeling of the treated part for twenty-four to seventy-two hours. General effects when large areas are treated, or there is a special sensitivity of the patient; they consist of flushing, general sweating, salivation, reduction of blood-pressure, increase of pulse-rate and peristalsis, and in some cases vomiting. These can be immediately checked by subcutaneous injection of $\frac{1}{100}$ grain of atropine.

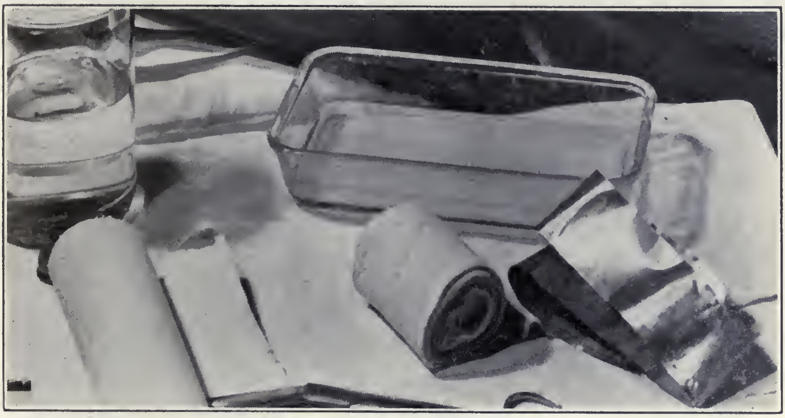

FIG. 111.—Equipment for mecholyl ion transfer; mecholyl solution, asbestos fabric paper, tray for moistening asbestos paper, electrode foil to place over moistened asbestos paper bandage to hold latter in place.

The effects of mecholyl ion transfer and of body heating on the cutaneous blood flow of the forearm and leg were measured by photoelectric plethysmographs.[18] Heat to the trunk resulted in profuse sweating and increased the flow 2.5 times in forearm skin and 3.5 times in leg skin. Cooling of the skin by evaporation probably prevented a maximal dilatation. Mecholyl ion transfer increased the flow 5 times in forearm skin and 6.5 times in leg skin. The greater dilatation with mecholyl probably represents the maximal blood flow which can be provided in the skin at normal levels of blood-pressure and therefore the maximum expansion of the cutaneous vascular bed. There is a question whether the so-called reflex thermal dilatation is entirely due to decreased vasomotor tone or to the direct effects of temperature on the vessels.

These observations make it evident that mecholyl administered by ion transfer penetrates the skin, is absorbed by the blood stream and exerts marked local as well as some general effect. In administering treatment it is desirable to keep the general effects at a minimum and exclude from treatment any patient with a history of asthma or hay fever.

Favorable clinical effects from mecholyl ion transfer have been reported in chronic arthritis of the rheumatoid type, in peripheral vascular disease in which spasm is a major factor, in Raynaud's disease, in thrombophlebitis and in varicose ulcers. For details see respective chapters. Pelvic ion transfer with mecholyl has been recently recommended for massive cellulitic infections (Chapter XXX).

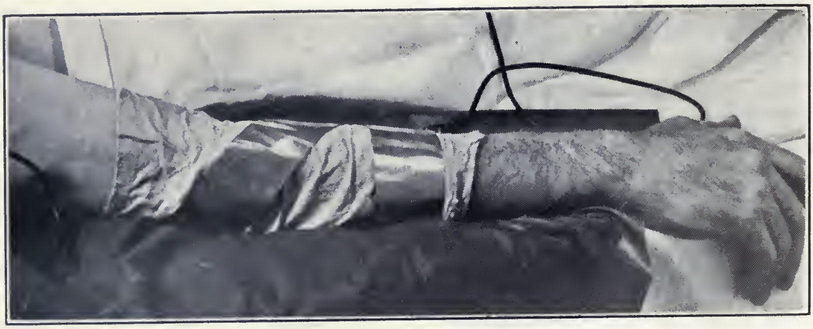

FIG. 112.—Mecholyl ion transfer treatment of elbow by asbestos fabric paper technique.

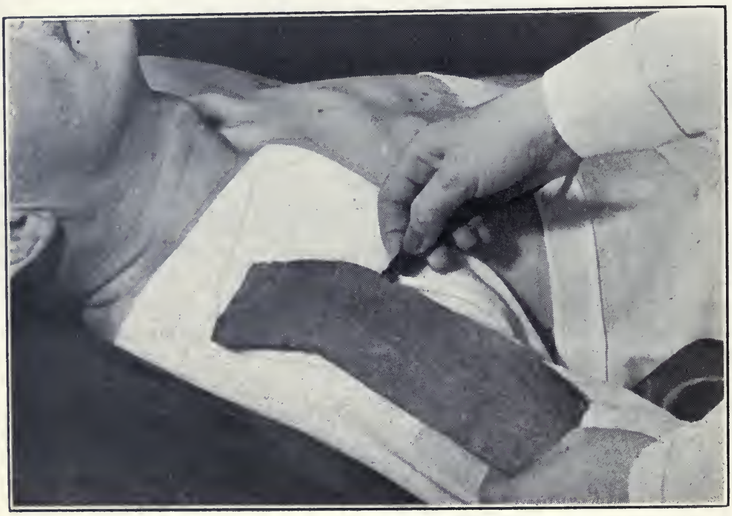

FIG. 113.—Mecholyl ion transfer treatment of shoulder by towel technique; placing of electrode foil over moistened towel; to be followed by wrapping a bandage or placing a small sandbag over shoulder.

The technique of mecholyl iontophoresis consists of saturating reinforced asbestos paper with a 0.2 to 0.5 per cent solution and wrapping it around the affected parts. The author keeps a 10 per cent stock solution on hand and dilutes a sufficient amount for each treatment. Instead of asbestos paper, thin hand toweling can also be used, it is saturated with the solution and snugly wrapped around the part to be treated. A fairly large malleable metal plate is placed on this wrapping and is connected to the positive pole of a galvanic generator; a very large dispersive, moist pad is applied to the back and connected to the negative pole. The current is slowly increased from 5 to 20 or 30 milliamperes and kept up for twenty minutes. After treatment the part is dried and kept covered.

Comparison has been made as to the relative value and practicability of histamine and mecholyl iontophoresis. Histamine applied by the generally used technique produces an intense local "counterirritant" effect and is applied in a very dilute solution for a few minutes only. Systemic effects are an exception. It is reported to give best clinical results in muscular affections. Mecholyl ionization produces a less intense local reaction, its effect amounting to a deposition of the drug in the deeper layers of the skin and its gradual absorption. It is applied in a more concentrated solution and for a longer period of time. Systemic effects occur as a rule. It appears to give best results in joint affections and also in varicose ulcers.

Other electropositive drugs:

Cocain.—Cocain iontophoresis with a 1 per cent solution applied for ten minutes at 1 milliampere strength per square inch is effective in anesthetizing a definite area of the skin or mucous membrane. Harpuder[8] considers electrophoresis of anesthetics of definite value for relief of referred pain or neuralgic or neuritic pain with localized hyperesthesia and hyperalgesia of the skin. The entire involved skin area is treated with a 1 per cent solution of nupercaine in 80 per cent alcohol containing 1:20,000 epinephrine for twenty to thirty minutes from the positive pole at 0.25 to 0.5 milliamperes per sq. cm. The skin becomes pale and remains hypesthetic for several hours.

Epinephrine.—The use of this drug has been recommended by Abramson[1] to reduce the severity of symptoms in the asthmatic state. The local reaction of vasoconstriction (blanching) acts to retard the absorption of the drug present in the deposits formed in the skin. Abramson soaked cotton with a solution of 1 per cent epinephrine dihydrogen phosphate, buffeted with phosphoric acid and applied it from an active electrode of about 30 sq. cm. area, for ten to fifteen minutes with a current of 5 to 7 milliamperes; he repeated this two to three times at each sitting.

Aconitine.—Aconitine is in addition to its effect on motor, cardiac and respiratory functions an antalgic. Barakin[2] has revived its electrophoretic use for relief in various neuralgias and plexus neuralgia. The active electrode is a gauze pad of sufficient size soaked with a 1 per cent solution connected to the positive pole and is applied towards the periphery of the affected nerve; current of 2 to 5 milliamperes is employed for thirty minutes or longer.

Calcium.—Calcium iontophoresis with a 1 per cent solution of calcium chloride has been recommended for old cases of hemiplegia by Bourguignon.[4] An active electrode consisting of a pad with a 1 per cent solution of calcium chloride is applied over one closed eyelid and connected to the positive pole; a dispersive pad connected to the negative pole is applied to the nape of the neck.

B. Applications From the Negative Pole

Chlorine.—In the standard technique of galvanism, in which moist pads are soaked with salt solution, under the negative pad chlorine ions are always liberated and at the same time sodium hydroxide is formed. The latter being mildly caustic, following a prolonged application, often will soften superficial scars; it may also affect more dense scars and make them more amenable to subsequent stretching and massage. For further details see Chapter XXXIII.

Iodine.—Good results have been reported by French and German clinicians, especially in Dupuytren's contracture, muscular infiltrations and in skin scars and scleroderma. It has been claimed that free iodine is liberated in the tissues during the passage of the current as shown by typical blue discoloration (iodine reaction) in the deep tissues. Iodine ionization has been recommended also for simple hypertrophic goiter and also for peripheral facial paralysis.

In the technique of application a pad electrode corresponding in size with the area to be treated is soaked in a 1 to 2 per cent solution of sodium or potassium iodide and connected to the negative pole of the galvanic generator, while the larger dispersive electrode is connected to the positive pole. Treatments should take from twenty to forty minutes at comfortable toleration.

Salicylic Acid.—Salicylic acid iontophoresis with a 2 per cent sodium salicylate solution has been recommended in rheumatic affections. It is introduced from the negative pole.

TABLE 20.—Uses of Ion Transfer

Conditions treated		Solution or drug employed	Active ion and polarity
Skin conditions	Fungus infections	Copper sulphate	Copper +
	Scleroderma	Mecholyl	Choline +
	Varicose ulcers	Mecholyl	Choline +
	Indolent ulcers	Zinc sulphate	Zinc +
	Keloids	Potassium iodide	Iodide −
	Recent scars	Sodium chloride	Chloride −
Medical-surgical conditions	Chronic arthritis	Mecholyl	Choline +
	Peripheral vascular disease	Mecholyl	Choline +
	Rheumatic and traumatic conditions	Histamine dihydrochloride or ointment	Histamine +
	Hemiplegia	Calcium chloride	Calcium +
Gynecological conditions	Chronic endocervicitis	Copper sulphate	Copper +
	Cervical erosion	Copper sulphate	Copper +
	Pelvic inflammation	Mecholyl	Choline +
Nose, throat and eye conditions	Chronic otorrhea	Zinc sulphate	Zinc +
	Vasomotor rhinitis	Zinc sulphate	Zinc +
	Trachoma	Zinc sulphate	Zinc +

Dangers in Galvanism.—The chief danger in all galvanic treatments is the occurrence of skin burns or excessive destruction of the mucous membrane; these are always due to excessive density of current. Molitor and Fernandez[16] found that a definite relation ratio of 3 to 4 exists between current density producing pain and that of producing burns. Therefore it is inadvisable to depend on pain sensation as a criterion for prevention of burns, but keep current strength always in relation to the size of electrodes. Another potent cause for burns is the touching of the skin by the electrode metal, insufficient padding or denuded areas in the skin. If the metal touches the skin as shown in Figure 114, burns are produced by a much lower current, evidently because of excessive currrent density at the point of contact.

In copper iontophoresis excessive amount of current applied to the cervix can cause undue amount of late sloughing and subsequent stenosis of the cervix. In zinc iontophoresis of the nasal mucosa excessive current strength may cause permanent damage to the nasal mucosa and impairment of the sense of smell.

In mecholyl iontophoresis excessive dosage or individual sensitivity may cause unwanted systemic reaction.

Safety Rules in Galvanism.—In addition to the general rules of treatment described in Chapter V, the observation of the following *special* rules will safeguard the patient in all galvanic treatments and electrophoretic treatments.

1. Be sure that the patient's skin sensation is normal; otherwise calculate and control the current strength carefully in accordance with the size of electrodes and the milliammeter reading.

Fig. 114.—Effect of uneven distribution of current. Ten milliamperes flowing for fifteen minutes through a well-padded electrode with a thin, cross-shaped metal sheet placed between the padded electrode and the skin. (Molitor and Fernandez.)

2. Do not apply the current over denuded areas and be most careful when over recent scar tissue.

3. See that the metal plate of the electrode is evenly covered by the padding and that there are no bare edges in contact with the skin.

4. See that the covering pad is evenly soaked with tap water or saline solution.

5. Apply electrodes in good contact, and with even pressure. Uneven pressure from tight bandaging or from folds or creases in the pad and insufficiently moistened areas lead to uneven distribution of current, the first subjective manifestation of which is a burning sensation in one or more spots. If the patient complains of burning at any time during treatment and the amount of current does not seem excessive, the first thought is uneven current distribution or insufficient moistening of the pads. The remedy is to shut off the current, take off the pads, remoisten them and reapply them carefully.

6. Fasten the conducting cords securely to the electrodes, making sure

that the metal of the cord tip does not come in contact with the bare skin at any point.

7. Always advance current gently when starting; never close the current sharply while the milliammeter registers current flow.

8. Be sure that the patient understands that he is to report undue burning or pain at once. The individual judgment of patients as to what they feel as burning or pain varies considerably, so that it is a safe rule never to apply more current than the patient states is comfortable, no matter what the milliampere reading shows; but, on the other hand, never exceed the safe milliammeter reading, in relation to electrode size; even if the patient claims that he can stand more current. One should bear in mind that in the course of galvanic treatments the meter reading has a tendency to mount as skin resistance decreases. If the opposite occurs, this is usually a sign that the pads are becoming dry and need remoistening.

9. If at any time the patient complains of annoying symptoms, decrease the strength of current; then, should this not afford relief turn off the current entirely, take off the electrodes and investigate.

10. After conclusion of treatment, do not allow patient to go outdoors with underwear or other clothing wet from the galvanic treatment.

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CHAPTER IX

CURRENTS OF LOW FREQUENCY

Historical: General Considerations. Physics and Physiological Effects: (1) Interrupted Galvanic Current. (2) The Faradic Current, The Surging Faradic Current. (3) The Slow (Galvanic) Sinusoidal Current. (4) The Modulated Alternating or Interrupted Sinusoidal Current. Low-frequency Apparatus. Therapeutic Aspects of Electrical Muscle Exercise. Clinical Use of Low-frequency Currents. Choice of Current. General Technique. Individual Motor Point Stimulation and Group Stimulation. Dangers of Application. Static Electricity.

Historical.—Galvani observed first in 1780, the twitching of the muscles of a frog's leg under the influence of electricity; Volta proved twenty years later that this was due to the sudden "make" of the current flow in an electric cell. The induction or faradic coil was discovered by Faraday in 1831; Duchenne in 1855 described its application for electric stimulation of muscles. Remak first demonstrated the motor points for accurate electrical testing of muscles. Du Bois Reymond in 1849 formulated the law of electrical muscle and nerve stimulation and first employed the induction coil for muscle stimulation. He also made the first make and break key for interrupting an electric current. Bergonie of Bordeaux constructed the first device for general electric muscle stimulation by faradism; Kellogg, of Battle Creek, described the first sinusoidal muscle stimulating apparatus. The newer methods of electrodiagnosis by condenser discharges and chronaxia testing as presented in Chapter VII, also led to the employment of these newer forms of low frequency devices for therapeutic muscle stimulation.

General Considerations.—Under the term of currents of low frequency a variety of currents are included. Their common physical characteristics are that their voltage or tension is constantly changing and is quite low—as a rule, there is only a few milliamperes of current flow between the electrodes applied to the body. Their primary physical effect is a sudden change of ionic concentration in the tissues affected; their physiological effect is a stimulation of motor and sensory nerves. The term low frequency relates to a rate of change or frequency below 10,000 per second; in contrast, high-frequency currents with a rate of frequency over 100,000 per second do not cause any stimulation of excitable tissues.

The therapeutic importance of low-frequency currents is twofold: (1) They furnish a characteristic procedure known as electrodiagnosis for the recognition of pathological conditions of the motor tract; (2) they furnish means for the stimulation of weak or paralyzed muscles, a form of electrical muscle exercise valuable in the treatment of injuries and diseases.

We have seen in Chapter VI that an electrical stimulus exerting ionic changes with sufficient suddenness over muscular parts or motor nerves, acts as an impulse for muscular contraction. The steadily flowing galvanic current causes no muscular contraction because there is not enough change in its strength or its rate of fluctuation to act as a stimulus. Only when the flow of the current is suddenly started or broken at sufficient strength, over a muscle or motor nerve, does a contraction occur. The extent and type of these contractions varies with the intensity, form, and duration of the electrical stimulation and the condition or type of muscle affected.

In normal skeletal muscles (with an intact nerve supply), if the number of alterations or interruptions of the current is below twenty per second such as in case of an interrupted galvanic current, single (clonic) contractions occur; if they are above twenty, such as in case of stimulation with a faradic type of current, prolonged (tonic or tetanic) contractions result. In muscles of normal physiological state, contraction is of a tetanic type and always the result of indirect stimulation through the nerve which is more excitable than the muscle. When the motor nerve has degenerated as a result of trauma or disease it cannot be stimulated, and then the independent property of contraction of the muscle becomes evident. Such response, however, is of different character; because of the secondary degenerative changes in the muscle, it is sluggish and worm-like instead of the normally brisk contraction. It also requires an electric stimulus of longer duration and greater volume for its production. This qualitative-quantitative change in the type of electrical reaction known as the reaction of degeneration, has been fully described in the chapter on electrodiagnosis. Hence it is evident at the outset, that for effective stimulation of muscles, just like in electrodiagnosis, at least two types of stimuli are required; one relatively quick and rapid to stimulate muscles with intact nerve supply and one relatively slow to affect denervated muscles.

All forms of low-frequency currents act as a stimuli to both motor and sensory nerves, hence they will cause not only muscular contraction, but also a variety of sensations, ranging from simple tingling to actual pain, according to the mode of application.

Physics and Physiological Effects.—For a number of years manufacturers of apparatus have turned out apparatus furnishing a bewildering variety of low-frequency currents and there was no universally accepted terminology. To a large extent this situation still prevails. We will describe the four principal forms of low-frequency currents and present some experimental demonstration of their action.

1. **The Interrupted Galvanic Current.**—The interrupted galvanic current is usually produced by a mechanical device placed in a galvanic circuit that interrupts the current flow at regular intervals, such as 30, 60, 120 times per second, as shown by an indicator. A make and break key in the operator's hand, usually mounted on the handle of the testing electrode, is the simplest means for muscle and nerve testing or stimulation with the galvanic current when single contractions are wanted. The strength of the current is regulated by a rheostat.

Experimental Demonstration.—The subject places the palm of one hand over a wet pad electrode, about 3 x 4 inches in diameter, connected to the positive pole of a galvanic generator. A wet-padded disc electrode, about 1 inch in diameter, mounted on an interrupting handle and connected to the negative pole, is placed over the middle of the belly of the biceps muscle. The forearm is well supported and the biceps thus relaxed. A current of about 5 milliamperes is turned on. The subject feels a slight stinging under both electrodes, especially under the smaller one. The current is now suddenly "broken" by the interrupting handle and brisk contraction of the biceps occurs. Contraction can be produced with less current by starting ("making") the current with the electrodes in the same position, as the make of current is more effective than the break.

This experiment proves that while the galvanic current flows steadily it exerts only mild sensory effects, due to skin stimulation; if the current applied over muscles at sufficient density is interrupted, a brisk single contraction occurs at the make and the break.

Besides the muscular effect as described, the sudden ionic change of the interrupted galvanic current causes painful stimulation of the sensory skin endings. This stimulation is distinct from the sensation which accompanies the muscular contraction produced by the same current. It has been shown that "electromuscular sensibility" is caused by the irritation of intramuscular sensory nerves and is a dull, tensile sensation which increases with the strength of the current until it may become actual pain.

Single contractions as brought about by the make and break of the galvanic current are not physiological types of contractions, because we have seen in Chapter VI that all forms of voluntary muscular contractions are of tetanic nature and the cells of the brain send out not a single stimulus, but successive volleys of impulses.

The make and break of the galvanic current serves in electrodiagnosis for testing of the response of the muscles and nerves; it also serves in treatment for the stimulation of extremely weak muscles before they begin to respond to the more physiological form of rythmically increasing muscle stimulation by a surging current.

2. **The Faradic Current.**—The faradic current is produced by a faradic or induction coil, described in Chapter III. The "primary" current produced in a faradic coil is essentially a direct (unidirectional) current rapidly made and broken. This current induces in the secondary coil at its make a short flow of current in the opposite direction, while at the break the induced current flows in the same direction as the original primary current. The "secondary" current of a faradic coil is the current employed in electrotherapy, and the one commonly known as the faradic current.

Due to "self-induction" in the primary current, which at the make retards and at the break increases the currents formed in the secondary, the "break" current in the secondary is much stronger than the "make." It lasts usually only about one-thousandth second, and its frequency is the same as that of the primary current. The make part of this current in the secondary can be disregarded from the standpoint of muscle stimulation and the *effective part of any faradic current is essentially a very abruptly interrupted unidirectional current.* The number of interruptions is usually from 80 to 100 per second.

The sensory effect of the faradic current is even more marked than that of the interrupted galvanic current. It causes sharp stinging and jarring sensations which increase in intensity as the current strength increases. If a sensory nerve is directly stimulated the sensation is felt in its entire area of distribution. Like the effects of the interrupted galvanic current, the painful sensations caused by the faradic current contain two elements, cutaneous and muscular.

The faradic test on page 113 shows that if the testing electrode is applied to a normal motor nerve, all muscles supplied by the nerve below the point of stimulation will go into continuous contraction. If a faradic type of current is applied to a normal muscle or motor nerve it excites a tetanic contraction. The rapid succession of stimuli occurring at a rate of 50 to 100 within a second keeps up the contraction produced by each preceding stimulus, and thus a continuous contraction of the muscle takes place. Such a condition is known as a muscle tetanus. The tetanic contraction, however, will not go on indefinitely and after a varying number —from 40 to 50 contractions—the muscle becomes exhausted and will relax. A muscle exhausted by repeated stimulation will recover after a period of rest.

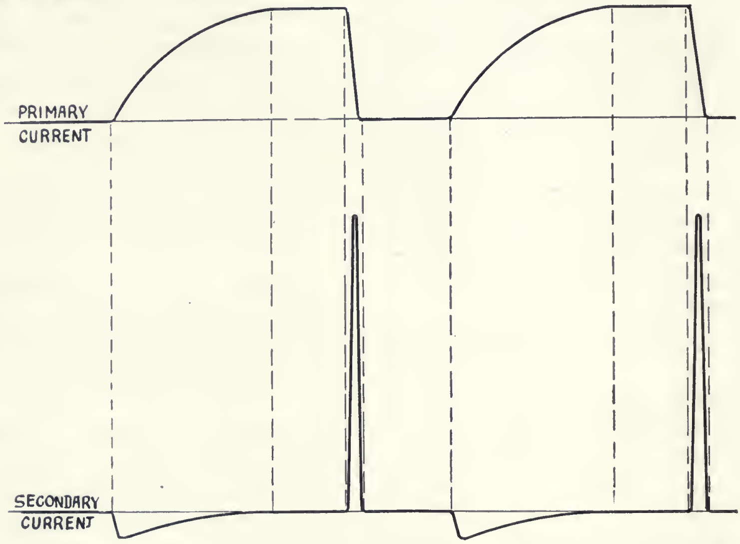

FIG. 115.—Diagram showing direction of current in primary and secondary induction coil at the make and break.

The faradic current differs from the interrupted galvanic in the following ways: (1) The voltage of the faradic current is higher and its amperage is correspondingly lower, because the difference in the ratio of wiring between the primary and secondary coils of the faradic apparatus amounts to that

FIG. 116.—Myograph of muscle tetanus under continued faradic stimulation. Contractions cease when muscle becomes exhausted.

of a step-up transformer. (2) There is no electrolytic effect because, although the current flow at the make can be disregarded for practical purposes it represents an amount of current flow equal to that at the break and thus they neutralize each other's effect. When applying this current for electrical muscle and nerve testing, therefore, it is irrelevant to which terminal of the coil the testing electrode is connected. (3) The faradic surges are often irregular, because of the mechanical features of the electromagnetic make and break arrangement in the primary circuit.

Standard dimensions for a faradic coil were decided upon at the International Electrical Congress of 1881, and unless each faradic coil is constructed in accordance with these specifications—which is not—each coil is a law unto itself. In actual practice the only way to gauge the dosage of the faradic current is according to the sensation of the patient and the strength of the muscular contractions produced.

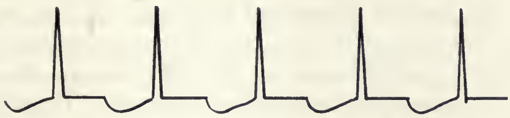

Fig. 117.—Graph of faradic current.

The intensity of a faradic current is regulated through varying the relative distance of the primary and secondary coil thus changing their inductive capacity. The secondary coil is usually movable on a track. This track is provided with a centimeter scale; each number thereon is simply a relative indication of the strength of the current produced in the secondary.

In small dry cell faradic batteries the primary and secondary coils are usually wound one upon the other in a fixed position and a movable hollow metal cylinder serves as a regulator. As it is drawn out or pushed in between the iron core and the primary coil, it interferes with the magnetic field: the current is weaker when the shield is entirely over the core and becomes proportionately stronger as the shield is drawn out. (Fig. 126.)

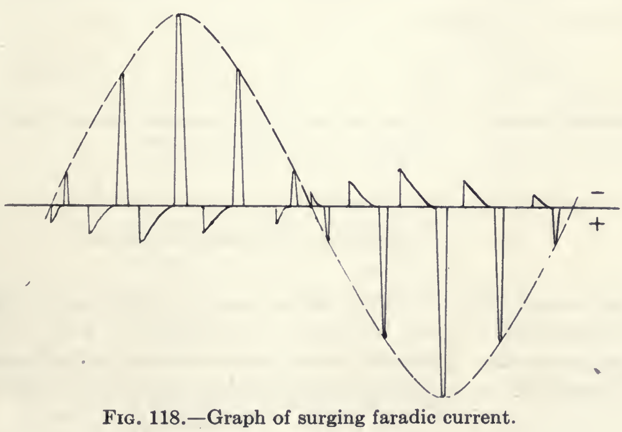

Fig. 118.—Graph of surging faradic current.

The continuously flowing faradic current is chiefly employed in electrodiagnosis for muscle testing; it is not suitable without gradual surging for electric muscle exercise because of its painful tetanizing effect.

The Surging Faradic Current.—In the older type of galvanic-faradic cabinets, motor-driven devices "surge" the faradic current by interposing a varying resistance. (Fig. 118.) This arrangement allows the use of the current with a gradual rise and fall in its voltage, causing graduated muscular stimulation without a tetanus. In the Smart-Morton coil a sliding coil moved by the operator causes suitable surging of the current. These surging forms of current which allow alternate contraction and relaxation of muscles are the most desirable form of exercising current for non-paralyzed muscles. (Fig. 126.)

In newer type of low-frequency apparatus with thermionic tubes, it is possible to produce a current with the approximate characteristics of the induced current of the faradic coil. Variations in the thermionic circuit surge the current.

3. **The Slow (Galvanic) Sinusoidal Current.**—If a galvanic current is passed through a rhythmically varying resistance which at the same time periodically reverses the direction of flow of the current, a reversing galvanic wave or slow sinusoidal current is produced. Thus defined, a sinusoidal current consists of rhythmical waves, each of which gradually increases in intensity and volume from zero to maximum and without a pause decreases to zero and then repeats the same process in the opposite direction. Five to thirty periods in a minute is the usual rate at which the galvanic sinusoidal current is employed. The commercial alternating current as well as the alternating current produced by the various motor generators are also sinusoidal currents according to the above definition. The principal difference between these reversing currents is the frequency of their reversal or alternation, varying from a few per minute in the slow sinusoidal to a hundred or more per second in the other forms. It has been attempted to classify sinusoidal currents as slow, medium and rapid ones; there is, however, as yet, no generally accepted figure according to which this distinction may be made. According to Krusen it has been suggested that when the duration of flow in one direction is not greater than $\frac{1}{50}$ of a second, such a sinusoidal current be called rapid.

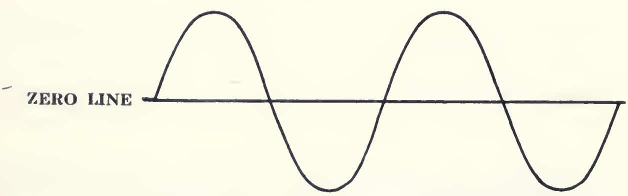

Fig. 119.—Graph of sinusoidal galvanic current.

It has been established by both clinical and experimental evidence that the slow sinusoidal current furnishes a stimulus of long duration and slowly surging quality. Smooth muscles and skeletal muscles in the stage of flaccid paralysis respond to such a stimulus, while they cannot be stimulated by the normal quick forms of electrical stimulation.

The slow sinusoidal current is the main standby in the treatment of paralysis with the involvement of the lower motor neuron, such as peripheral nerve injuries and infantile paralysis, in the stage when there is no voluntary power of contraction and no response to the faradic type of stimulation. For exercising weak muscles without motor nerve involvement this current is not so pleasantly tolerated and not so effective as the surging currents of more rapid frequency.

4. **The Modulated Alternating or Interrupted Sinusoidal Current.**—The ordinary alternating current from the lighting circuit in its usual form of 60 cycles or 120 alternations per second when applied to muscles and nerves has an effect similar to the faradic current; it brings about a tetanic contraction and is quite painful. In some apparatus a surging device enables the application of this current—labeled as rapid sinusoidal current —for treatment purposes. Most of the present type generators provide a current of somewhat more rapid alternation, with a surging or gradual rise and fall of voltage and they usually label it as the rapid sinusoidal current. As the voltage of successive stimuli gradually decreases and increases, there is no tetanus and, due to the rapid alternation within each surge, the polar or electrolytic effect is minimal. As a result, a current of medium strength causes little skin sensation and is usually well tolerated. Among these modifications is the Morse wave current with 360 alternations per second.

The variations of this modulated alternating current as to frequency and as to shape and duration of each surge are numerous. These currents exert the same effects for muscle stimulation as those of the surging faradic type, *i. e.*, graduated contractions in muscles with intact nerve supply.

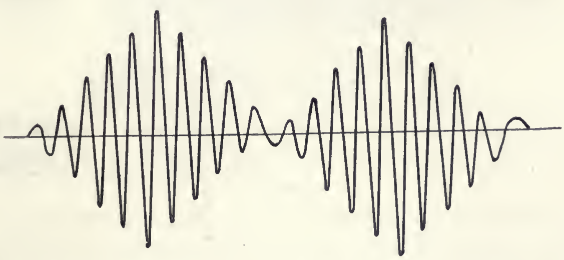

Fig. 120.—Graph of one variety of surging or modulated alternating current.

Table 21.—Classification of Low-frequency Currents

Current	Physics	Principal use
Interrupted galvanic	Unidirectional low tension current rising and falling at a frequency of 30 to 120 p. second	Electrodiagnosis; stimulation of denervated muscles
Faradic	Asymmetric, interrupted, alternating current of higher tension; frequency about 100 a second; single impulse lasts about $\frac{1}{1000}$ second	Electrodiagnosis
Surging faradic	Gradual rise and fall of faradic impulses	Stimulation of muscles with intact nerve supply
Modulated alternating (rapid sinusoidal)	Rapid alternations of 60 to 90 cycles per second; may be surged (modulated); single impulses last about $\frac{1}{100}$ second	Stimulation of muscles with intact nerve supply
Galvanic sinusoidal or wave	Alternating current of 5 to 30 cycles per minute; single impulse lasts $\frac{1}{50}$ second or longer	Stimulation of denervated muscles

LOW-FREQUENCY APPARATUS

The variety of pathological conditions underlying muscular weakness and paralysis explains the need for a certain variety of low-tension and low-frequency currents. Unfortunately, so far, there is as yet no universally accepted standard for the construction of low-frequency apparatus and for the measurement and comparison of the different currents produced.

The requirements for an apparatus furnishing low-tension and low-frequency currents would appear to be as follows: It should run on either the commercial direct or alternating current; it should allow modification of both amperage and voltage; it should produce surges of any desired frequency and duration so as to allow gradual contraction and relaxation in all types of muscular weakness and paralysis; it should furnish a slow smooth galvanic wave and preferably serve also as a source of smooth galvanic current.

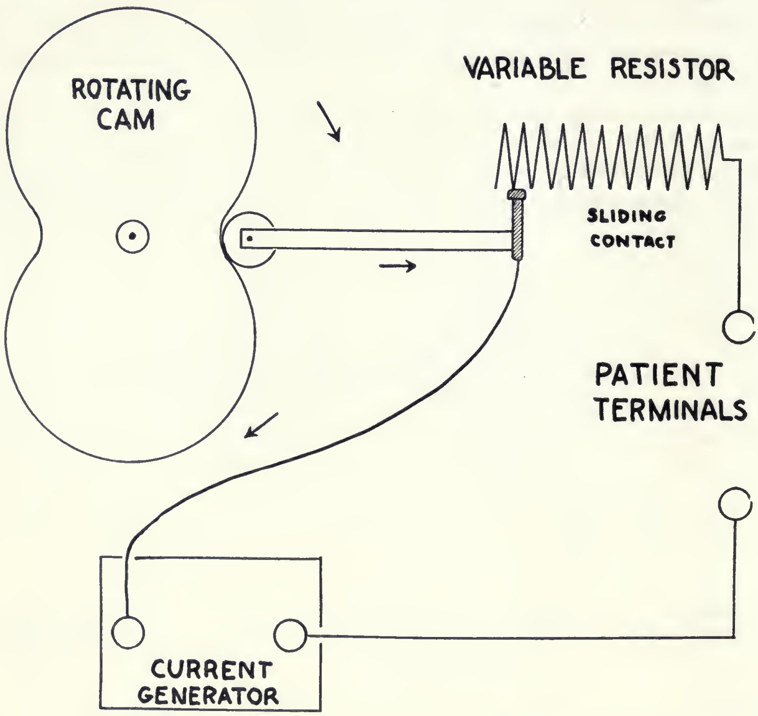

Fig. 121.—Diagram of variable resistor for producing surging low-frequency currents.

In present-day practice there are two main types of apparatus for generation of a variety of low-frequency currents, motor generators and thermionic tube types of generators.

Motor Generators.—The main features of motor generators have already been described in the previous chapter. Motor generators can furnish a large variety of low-frequency currents, and manufacturers have been entirely too eager to outbid each other by offering a multiplicity of such varieties, for which no real need exists.

The advantages of motor generators are: (1) The currents furnished are "earth-free," there is no connection between the patient's circuit and the supply current; hence there is no danger of shock to the patient if an accidental contact with a grounded line is made. (See Chapter XIV.) (2) In case of sudden break in the outside circuit or blowing of a fuse, the motor of the apparatus will keep on turning for a short time on account of its momentum and there will be no shock of a sudden interruption—an important consideration when applying, for instance, galvanism to the brain. (3) A reasonable variety of currents is obtainable. The disadvantages of motor generators are their more complicated structure with many moving parts, their bulkiness and their much higher price.

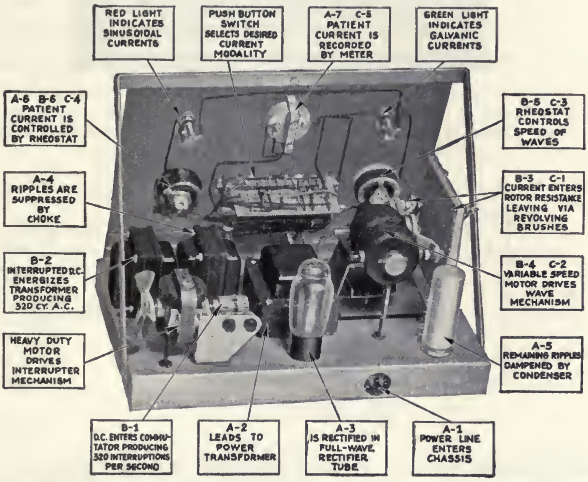

Fig. 122.—Interior view of low-frequency apparatus showing combination of motor-driven wave mechanism and rectifying tube. (Courtesy of the McIntosh Electric Corp.)

Among the well known types of motor generators are the Morse wave generator and the Polysine generator. In the first one an armature revolving in a magnetic field provides an alternating current of 360 alternations a second. A set of cams which can be slipped in and out of the machine serve to vary the distance between the armature and the pole pieces and produce from 11 to 36 rhythmic surges per minute. These also make it possible to alter the shape and peak duration of each wave. Thus a varying form of stimulation with intervening periods of rest can be produced. The Polysine generator is a combination of a motor and alternating current generator in a single housing, furnishes a 350 cycle "rapid sinusoidal" current which can be suitably modified as to shape and duration of its waves. In both generators a rectifier and additional filtering also provide a smooth galvanic current and its variations.

Generators of Thermionic Tube Types.—Vacuum types of generators have come into general use in recent years. They utilize a variety of devices: vacuum tubes for rectifying the alternating current; grid glow and thyratron tubes to rhythmically change its strength and frequency without any sort of rotating mechanism. The advantage of these generators is their lower cost, lesser weight and the absence of moving parts, with silent operation and no need of lubrication.

A simple type of apparatus is that developed by Weiss[16] in which the 60 cycle alternating current is interrupted or surged at will by the combination of a thermal operated current interrupter (commercial sign "flasher") and vacuum tubes.

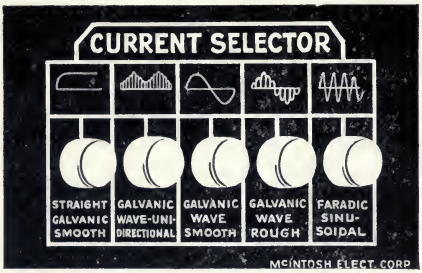

FIG. 123.—Push-bottom type modality selector of low-frequency currents, also showing oscillographic outline of wave forms. (Courtesy of the McIntosh Electric Corp.)

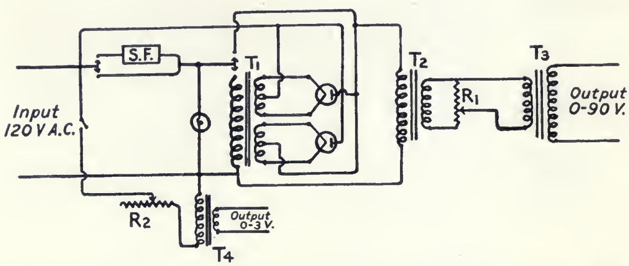

FIG. 124.—Basic circuit diagram of flasher sinusoidal generator (Weiss). The sign flasher (*S.F.*) can be switched in or out of the circuit. The first transformer (*T*) operates the filament of the surge vacuum tubes. The second and third transformers (T_2 and T_2) serve to render the control (R_1) electrically free of the remainder of the circuit, and also reduce the voltage at R_1 to accommodate an ordinary 30 ohm potentiometer. R_2 and T_4 form an optional current supply for a cautery loop.

FIG. 125.—Portable galvanic and faradic battery. The galvanic current is supplied by two 45-volt batteries contained in the cabinet. Useful at the bedside and where no lighting current is available. Current output is even while dry cells last.

Single Types of Low-frequency Apparatus utilize the current of dry cells or large radio batteries and are thus independent of the lighting current supply and easily portable; others are run on the ordinary alternating circuit.

Two portable types of faradic coils suitable for electrical muscle testing as well as for graduated electric muscle exercise are the *Bristow coil* and the *Morton-Smart coil.* Figure 126 shows the diagram of their construction. A laminated soft iron core when pushed into the induction coil increases mutual inductance and can be employed to surge the current. The output terminals furnish damped unsustained oscillations, the frequency of which depends on the capacity of the condenser and the inductance of the coils.

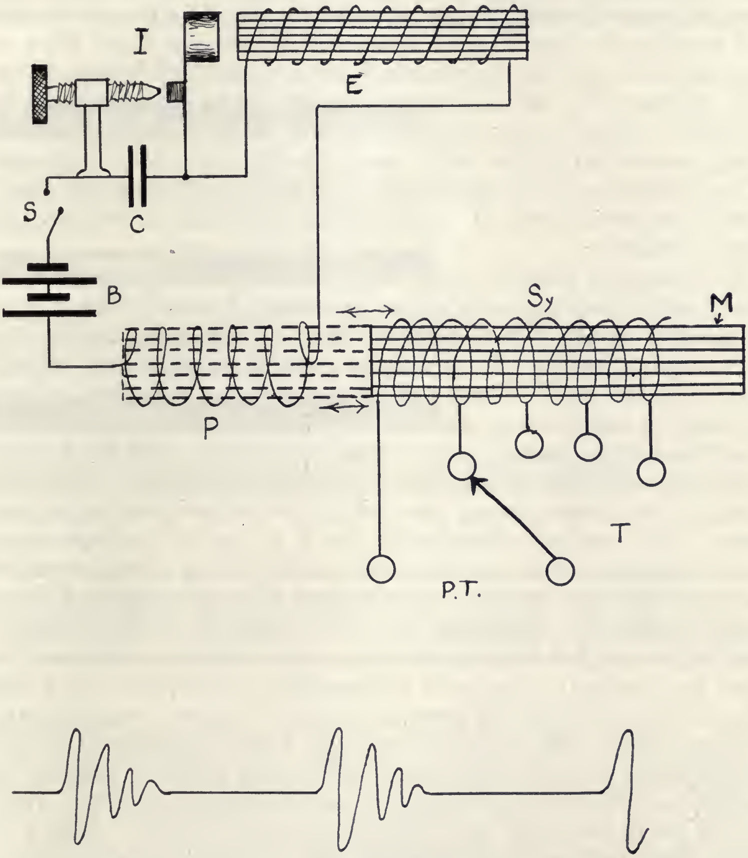

FIG. 126.—Diagram of faradic coil with hand surging and graph of oscillations produced. *T*, interrupter; *E*, electromagnet; *S*, switch; *C*, condenser; *B*, battery; *P*, primary; *Sy*, secondary; *M*, movable iron core; *T*, tap switch; *P.T.* patient terminals.

Therapeutic Aspects of Electric Muscle Exercise.—While there is no or only little controversy about the indications for electrical muscle exercise in simple muscle weakness, there is still considerable difference of opinion about the advisability of such exercise in real paralysis. Hence, it seems desirable to review the whole matter before presenting the indications for the clinical use of low-frequency currents.

In treatment of weak muscles there can be no argument on the point that voluntary exercise is the most desirable form of activity and that no other form of exercise can have the same physiological value. Yet there are a great many conditions in which natural muscle function is lost or diminished and encouragement of the restoration of function by artificial stimulation not only offers the usual beneficial changes resulting from muscle action but also directly encourages volitional effort on the part of the patient.

1. *In Muscles With Intact Nerve Supply.*—When muscles are atonic and wasted from any cause and voluntary exercise is not feasible, so long as the nerve path is intact, the production of painless graduated muscular exercise by electric stimulation reproduces the physical and chemical phenomena connected with normal muscular work. As a result the restoration of muscles to their normal physiological activity takes place more rapidly and all tissues in the neighborhood are benefited by the increased activity produced by the muscle movements in the circulation of blood and lymph. Acting as an external stimulus to physiological circulatory changes, muscle action not only mechanically assists in prevention of blood and lymph stasis but also lessens the formation of adhesions—perhaps the most frequent cause of long-standing disability after even minor injuries. (Smart.[13])

2. *In Denervated Muscles.*—The main function of every striated muscle is to contract in response to voluntary impulses. A muscle with an injured nerve does not contract voluntarily or reflexly and, being unable to perform its natural function of contraction, tends to revert to non-contractile connective tissue type. Since paralyzed muscles are unable to do any active work, it seems self-evident to many clinicians that a method which enables muscles to maintain part of their contractility and their nutrition is a desirable one. Electrical stimulation is the only known means for this purpose and its value is being attested by both clinical and experimental evidence. The earliest experimental work to prove the importance of electric stimulation in maintaining the nutrition of a muscle deprived of its nervous influence was performed over a hundred years ago, in 1841, by Reid, lecturer on physiology at the University of Edinburgh. The original object of his investigation was to settle the controversy over whether the property of muscle contractility is inherent in the muscle itself or is derived from the nervous system. In these experiments, the spinal nerves were cut across on four frogs, and the muscles of one of the paralyzed limbs were daily exercised by a weak galvanic battery, while the muscles of the other limb were allowed to remain quiescent. This was continued for two months, and at the end of that time the muscles of the exercised limb retained their original size and firmness and contracted vigorously, but those of the quiescent limb had shrunk to at least one-half of their former bulk and presented a marked contrast with those of the exercised limb. Subsequent animal experiments have proved that paralysis caused by cutting symmetrical nerve trunks will disappear quicker on the extremity treated by electricity than on the non-treated one (Bordier[1]).

Clinical experience in the treatment of large number of cases of peripheral paralysis has amply established the value of electric muscle stimulation. Pollock[11] states: "Electrotherapy serves to conserve vitality, prevent complete atonia, and increase the contractility of paralyzed muscles."

Souttar and Twining[14] state: "Were we limited in the treatment of peripheral nerve injuries to one method of treatment and had nothing but the muscle to consider we should ourselves prefer electrical stimulation to all other methods." On the other hand, some orthopedic men doubt any value of electrical muscle stimulation in paralysis and strongly voice their conviction that voluntary muscle exercise is the most desirable form of activity and no other form of exercise can have the same physiological value. Experimental evidence is being cited that electrical stimulation cannot retard atrophy and degeneration of denervated muscle and that the degree of regeneration of the peripheral nerve is not influenced by physical measures (Chor *et al.*[2]). Tower[15] maintains that because the atrophy of denervated muscles is due to a continuous fibrillation, leading to exhaustion of the muscle, electric stimulation does not appear rational.

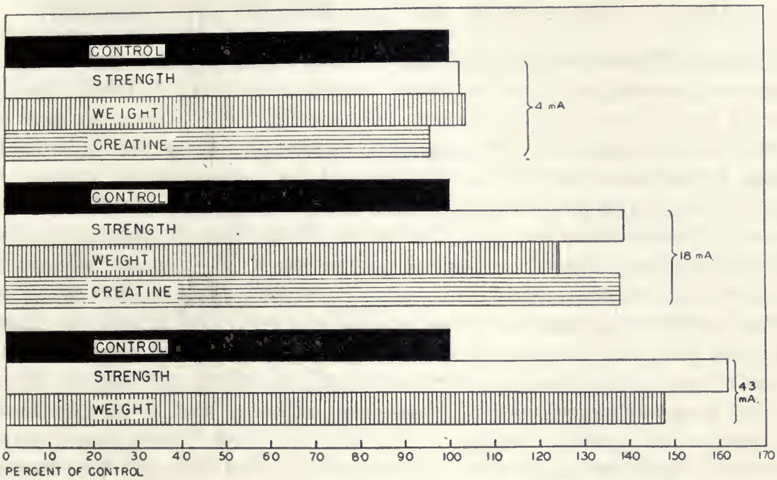

Fig. 127.—A graph showing average values for the effects of electrical stimulation on the rate of muscle atrophy. The stimuli were of different intensities (expressed in milliamperes) and applied for three minutes daily for fourteen days. The black bars represent the control expressed as 100 per cent. The control values were from non-stimulated denervated contralateral muscles. (Hines, Thomson and Lazard, courtesy of Arch. Phys. Ther.)

Very recent experimental work has corroborated the classical observations of Reid and added new evidence as to the value of electrical muscle exercise. Fischer,[4] experimenting with electrical treatment starting at various times after denervation, demonstrated that the best results are obtained with a treatment starting immediately after denervation, and that the strength and the duration of the electrical currents must be adapted to the changing excitability of the atrophying muscle. It is postulated that the electrical treatment causes mainly a training effect in the denervated muscle, similar to that in normal muscle, which only increases the size of the fibers and their metabolic capacity. In surveying the work done so far the same author states: "Preference of weak and ineffective stimulation for therapeutic use is astonishing." Gutmann and Guttmann[6] have demonstrated that electric stimulation accelerates the return of the muscle to its initial volume after reinnervation and possibly prevents atrophy; the muscles treated with interrupted galvanism showed better excitability and contractility as well as stronger reflex action, than those untreated. Liebesny[9] proved that such stimulation can produce response even in a completely fatigued muscle. Finally, Hines[8] concluded that electrical stimulation to the point of overstretching and even local fatigue does not appear to be detrimental to any phase of neuromuscular regeneration; but on the contrary, it delays atrophy and enhances recovery, if the stimulation is of sufficient intensity to induce strong contractions (Fig. 127).

On the basis of extended clinical use and of the enumerated experimental evidence it would appear that the case still stands for the judicious employment of electric stimulation in paralysis, alongside with other indicated measures such as heat, suitable support, and the earliest possible use of voluntary exercise. For further discussion of electrical stimulation in paralysis see Chapters XVII and XVIII.

CLINICAL APPLICATION OF LOW-FREQUENCY CURRENTS

1. **Simple Muscle Weakness.**—In the treatment of the various injuries incident to trauma graduated muscular contraction is said to be the greatest advance in physical therapy since the introduction of massage and can be used to the exclusion of massage. (Sherman.[12]) Its use is indicated in injuries to the soft parts, *i. e.*, muscle and ligament strains, sprains and bruises, both acute and chronic hematoma; adhesions of muscles which frequently follow the operative treatment of fractures, myositis, lumbago, torticollis, disuse atrophy, atony of the abdominal muscles after childbirth, low back trauma, acute and chronic synovitis, periarticular adhesions, synovial adhesions, wasting following dislocations and fractures, fibrous ankylosis, and for restoration of muscle strength following prolonged or chronic illness. The object of the treatment is to restore the tone to injured muscles, to prevent inter- and intramuscular adhesions, to keep the tendons and other parts moving so that they do not become adherent to contiguous structures, and above all generally to increase the blood supply to the injured tissues and to stimulate the rate of repair by rapidly promoting absorption of waste products.

The author's experience in the treatment of muscular weakness in traumatic conditions and of atrophy following disuse largely corroborates the claims of Smart and Sherman. In atrophy of the quadriceps following prolonged immobilization after fractures of the thigh or patella, in weakness of the deltoid and of other muscles following injuries, the systematic stimulation of muscles speeds up the restoration of muscle power and gives patients a feeling of increasing strength and comfort. For details see Chapter XXIX.

In atonic conditions of the abdominal wall, following operations, childbirth or associated with constipation, painless, rhythmic contractions applied systematically have proven useful in restoring the tone and contractility of muscles and the capacity for regular bowel action. For further details see Chapter XXV.

In functional paralysis resulting from traumatic neurosis, hysteria or neurasthenia electric stimulation is valuable as a stimulative treatment. (Chapter XVII.)

2. **Paralysis Following Nerve Injuries or Anterior Poliomyelitis.**—For the reasons already stated electrical muscle exercise is of the greatest

value in maintaining the functional properties of muscles in these conditions until normal nerve response returns. For further details see Chapters XXVII and XXVIII.

3. **Miscellaneous Indications.**—In the treatment of causalgia, the pain in amputation stumps of nerves, the Leduc current has been successfully employed. Reports on this treatment during the First World War state that it relieved painful sensations for hours with such certainty that it was even used as a diagnostic evidence of the real character of the lesion.

For the improvement of the muscle tone in cardiovascular disorders and in peripheral vasomotor disturbances low-frequency stimulation by the sinusoidal current may be employed through the medium of full or partial hydroelectric baths. (See Chapter VIII.)

Electrical muscle exercise is being employed for weight reduction (Chapter XXV). Faradic stimulation has been recommended for resuscitation in asphyxia of the newborn.

The most recent application of low-frequency currents is "electric shock therapy;" the employment of an alternating current to the brain once or repeatedly for inducing convulsions in the treatment of mental disorders. For details see Chapter XXVII.

Choice of Current for Muscle Stimulation.—It has been shown in Chapter VI that in order to produce a contraction, a current must have a certain minimal strength and there must be a certain minimal duration below which a current of minimal strength will not produce a contraction. If the minimal duration is reduced, no contraction will result unless the strength of the current is increased. The chronaxie is the minimal effective duration *time* over which a strength of current previously determined as the threshold of intensity must be applied to secure a maximal response. Besides the factors of the exciting agent, the electric current, the quickness of the excitability of the particular nerve or muscle treated must also be taken into consideration. This implies that in order to get an effective response the form and strength of stimulus employed must be adapted to the type and condition of muscle to be influenced.

The chronaxie of a healthy nerve has been found to be about $\frac{1}{1500}$ second, that of a degenerated muscle about $\frac{1}{50}$ second and involuntary muscle fiber may require a stimulus lasting for one second or more. As the quickness of excitability varies so much, it is evident that the duration of the stimuli employed must similarly be varied. It would be useless to apply a faradic stimulus with its time duration of $\frac{1}{1000}$ second to excite a paralyzed muscle with a chronaxie of $\frac{1}{50}$ second, for no contraction could result. On the other hand, the quick chronaxie of a healthy, neuromuscular mechanism requires a very rapid make and break to secure the maximum effect.

Grodins *et al.*[5] recently pointed out that it is unfortunate that the terms "galvanic" and "faradic" have become so deeply ingrained in the clinical and physiological literature. Actually, from a physiological viewpoint there is no sharp line of demarcation between them. They state that the ideal stimulating current for normal muscle would consist of a series of pulses of instantaneous rise which gradually increase in intensity from threshold to maximal and in frequency from zero to 100 per second. For denervated muscle, the ideal current would be of similar form, but the individual pulses would have to be of longer duration and of lower frequency and perhaps of more gradual rise. From this viewpoint "galvanic" current simply represents a "faradic" current of very low frequency. Osborne and Holmquest[10] state that the theoretical current best suited for stimulation of skeletal muscles with intact nerve supply is the surging interrupted direct current with alternate polarity. The interruptions are from 40 to 120 per second and the frequency of surge ranges from 5 to 100 per minute. Each current surge is followed by a period during which no

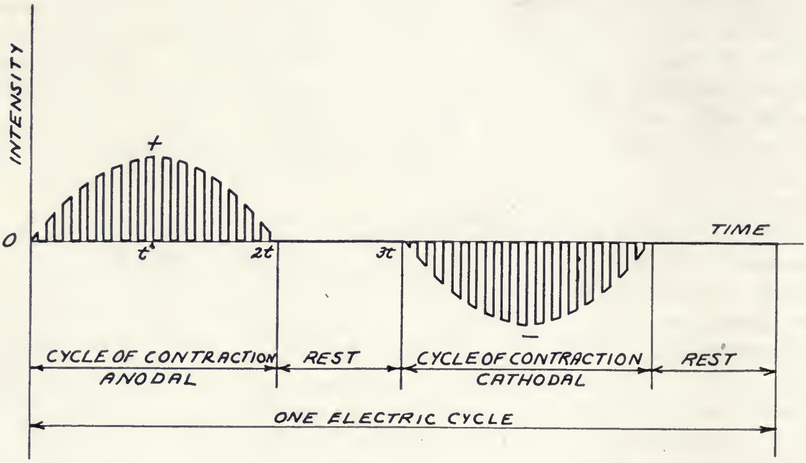

FIG. 128.—Theoretical current for muscle with intact nerve supply. (From Osborne and Holmquest's Technic of Electrotherapy; courtesy of Charles C Thomas.)

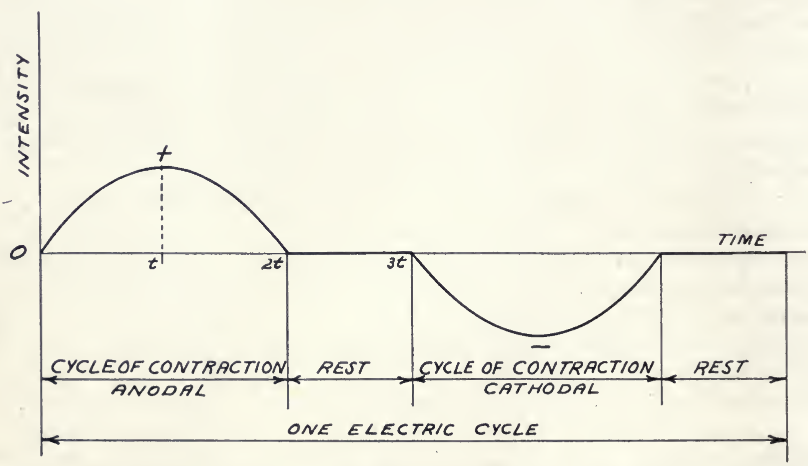

FIG. 129.—Theoretical current for muscle without nerve supply. (From Osborne and Holmquest's Technic of Electrotherapy; courtesy of Charles C Thomas.)

current flows (rest period). The ratio of the time of the surge of current to the time no current is flowing is about 2 to 1. For the stimulation best suited for a muscle without nerve supply, the same authors suggest the surging uninterrupted direct current with alternate polarity. Surge frequency, 10 to 20 per minute and each surge of current is followed by a rest period.. The ratio of the time of the surge of current to the time no current is flowing is about 2 to 1. (Figs. 128 and 129.) There is no such ideally constructed apparatus available in actual practice as yet, hence for the present one must use the clinically established methods of electrical muscle exercise.

Weak muscles with no organic nerve involvement respond best to a succession of very short stimuli, at a rate of 50 to 100 per second, sufficiently surged and spaced so as to allow gradual contraction and an intervening rest (relaxation). This is known as graduated muscular stimulation. For this purpose surged forms of the faradic type of current and the interrupted and modulated forms of alternating current serve best.

In muscle with spastic atrophy, such as following hemiplegia, the same type of stimulation as in simple atrophy of disuse can be applied, and a quick normal stimulus brings on the best response. There is a difference of opinion in the literature as to whether it is better to treat the spastic muscles themselves, teaching them how to relax following a contractile impulse or whether it is better to treat the opponents of the spastic muscles to minimize contracture and the effects of overstretching of the normal muscles. Further details as to technique will be found under Hemiplegia.

The treatment of spastic muscles by electrical stimulation is much less satisfactory than that of flaccid types of paralysis. It should be considered at best only as an adjunct to muscle training and re-education.

Muscles in the stage of flaccid paralysis respond only to a very slow rate of stimulation—10 to 20 per minute—and their contraction is sluggish and wormlike compared to the brisk contraction of normal muscles. A slow, smooth stimulus such as the slow (galvanic) sinusoidal is the current of choice. It produces a stimulus of long duration and slowly surging quality to which the paralyzed muscles respond gently and painlessly.

The use of the *interrupted* galvanic current for the eliciting of contractions gave rise to considerable controversy in the past. As long as we believe that it is beneficial to cause contractions in degenerated muscles, interrupted galvanism will supply a need in cases that do not respond to the slow sinusoidal current. It causes a response on account of its greater strength and longer flow.

Special Forms of Low-frequency Currents.—The Leduc Current is a galvanic current of 1 to 2 milliamperes strength and of a potential of 10 to 25 volts interrupted at a rate of 100 times a second, so that one-tenth of a period of current flow (make) is followed by nine-tenths of rest (break). Leduc claims that in animals he has produced experimentally single contractions, tetanus, local anesthesias, general anesthesia, coma, paralysis of the heart and respiration and, finally, death. Experimenting on himself and his assistants, he produced general anesthesia and electric sleep. The action of the Leduc current may be explained by the exhaustion of the sensory receptors by overstimulation. The local anesthesia seems to be identical with that obtained by percussing the skin rapidly and repeatedly.

Galvano-Faradization.—The combined use of the galvanic and faradic current is made possible by the use of a special switch incorporated in most of the older galvanic wall plates and known as the DeWatteville switch. At the same time, both currents can be surged by an evenly alternating resistance.

Condenser Discharges by Progressive Currents, the modified form of condenser discharges described under Electrodiagnosis, have been utilized by several clinicians, especially Turrell,[16] for selective stimulation of fully or partly degenerated muscles. Turrell claimed that the condenser method suppresses the excitation of the opposing normal muscles and effectively stimulates the less excitable paralyzed ones. The technique is based on the difference in the quickness of excitability between normal and abnormal

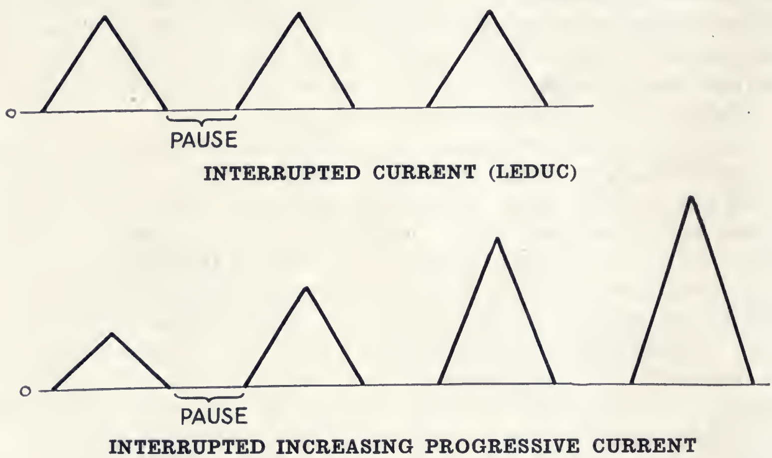

Fig. 130.—Graphs of interrupted and progressive current.

neuromuscular mechanism. A smooth galvanic current is used, which is interrupted by a metronome and regulated by a water resistance, with condensers in parallel, varying from a capacity of 2 microfarads to 30 microfarads. Owing to its gradual onset, the stimulation is almost painless.

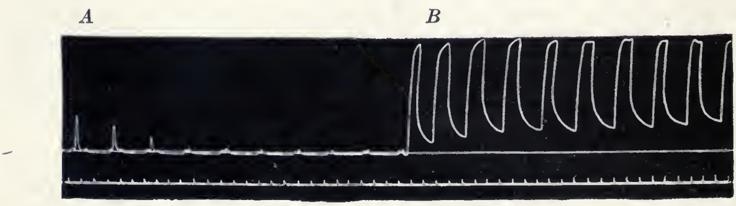

Fig. 131.—Comparative diagram of results of muscle stimulation of paralyzed muscle (*A*) by interrupted galvanic current; (*B*) by progressive Leduc current. After five minutes' stimulation with 6 milliamperes of interrupted galvanic muscle was completely fatigued, but with 4.6 milliamperes of progressive Leduc current vigorous contractions started again. (Dr. P. Liebesny.)

The apparatus is simple and inexpensive and Turrell reports equally good results in flaccid stages of Bell's palsy and infantile paralysis. Liebesny[9] reported on the successful use of this method. He describes it as an interrupted and progressive current (Leduc) and the results claimed call for further clinical corroboration when suitable apparatus will be more generally available.

GENERAL TECHNIQUE OF LOW-FREQUENCY STIMULATION

Electrical stimulation of muscles may be carried out by two forms of technique: individual stimulation or group stimulation. At times a combination of these two procedures is advisable.

Individual Motor Point Stimulation.—This technique consists of applying to each muscle a low-frequency current of just enough strength to bring about its stimulation.

The patient is placed in a comfortable position, where the parts to be treated are well supported and relaxed. These parts should be warmed up by the preliminary application of a heat lamp or hot towels. A fairly large (at least 3 x 4 inches) moist pad dispersive electrode is placed upon a part of the body where there are no muscle bellies—the sternum, the spine or a remote part of the extremity under treatment. An active small moist pad electrode—1 inch in diameter—and preferably with an interrupting key, is placed in good contact with the skin over the middle of the muscle belly. This part also known as the *motor point* is the area where the muscle normally responds to the minimum amount of current. It takes practice until the operator becomes an expert in locating quickly the best point of stimulation in each muscle.

FIG. 132.—Stimulation of facial nerve—active electrode over motor point—dispersive electrode under palm of hand.

As muscle stimulation is, as a rule, done by a surging current, sudden painful stimulation by the current is usually absent. Nevertheless the amount of current flow should be kept down at first to the lowest possible degree compatible with comfort. It must be remembered that with low-tension currents considerable amount of skin resistance has to be overcome and therefore an impulse which at first will not penetrate well enough to cause muscular response on being repeated at the same strength may after a few seconds act as a stimulus of sufficient strength. For this reason too rapid shifting of the active electrode must be avoided. Once a muscular contraction is produced, the operator must see to it that it is followed by sufficient relaxation, before the next impulse is started. With the double control of current strength and frequency there should be no difficulty in administering stimulation at the proper strength and spacing.

The number of contractions to be elicited will depend entirely on the degree of weakness and type of response and may vary from one or two in a fully paralyzed muscle to ten in a case of simple weakness. The second contraction should be a little stronger than the first, the third still a little more strong; subsequent contractions should be about the same strength, their spacing depending on the time it takes the muscle to relax fully before the next stimulus is applied. No mechanically controlled rate of stimulation can be ever so efficient and pleasant as stimulation done with individual setting for each and every stimulus, such as is made possible for instance by the faradic types of apparatus controlled by an adjustable core, hence its appropriate designation as "graduated muscle exercise."

Smart[13] states that a skilled operator can cause a group of muscles to contract at a rate of 90 contractions per minute and if carried out for thirty minutes, this will result in the group contracting 2700 times. Large groups of muscles such as the quadriceps are more able to withstand prolonged treatment without showing signs of fatigue than the interossei of the hands or feet or an isolated muscle such as the adductor longus or sartorius.

In the average case of paralysis the method of unipolar stimulation is preferable, with a large dispersive electrode over the cervical or lumbar spine or at any place central to the lesion and a small active electrode over the individual muscles. In all these cases the normal motor point is displaced distally (toward the tendon) and to save time in subsequent treatments it is advisable to mark with indelible pencil the most effective point of stimulation for each muscle. In the early stage of fully paralyzed muscles one must be well aware of the danger of overexercising muscle by electricity. Not more than a flicker of the tendon is necessary to prove a successful contraction in a paralyzed muscle. This flicker may not even be visible; it is enough when it is palpable to the trained finger at the insertion of the tendon. It is interesting to note, that at first it may be necessary to use a larger amount of current to cause contractions but that after the first one or two contractions we can elicit response with markedly less current. One can aptly express it by stating that the muscle needs "waking up" at first and then responds more briskly. From 3 to 10 contractions of each muscle are ample at the start, with an increase to the maximum of 30 to 40 effected gradually. A careful operator will very quickly notice that a larger amount of current is needed in case of a muscle that has been overtired previously. Preceding and during electrical treatment the affected extremity should be placed so that the paralyzed muscles are relaxed and not kept on a stretch by their healthy antagonists and the maximum treatment time to an individual muscle should be from two to three minutes and about fifteen minutes to an entire extremity.

The signs of overstimulation in strength or frequency in any muscle are: a slower rate of contraction and relaxation, a well-marked tremor during contraction; several hours after treatment there may be a feeling of stiffness and pain instead of the usual prolonged feeling of comfort. At the first sign of fatigue stimulation should be shifted to an adjacent muscle or group of muscles.

A special form of individual muscle stimulation in extremely weak muscle consists of *bipolar stimulation* by two equal-sized active electrodes placed at the two ends of a muscle belly. (Fig. 77.) This method is only applied when the muscle is so extremely weak that the current strength necessary for a palpable response causes very strong contraction in the neighboring muscles and this often makes it impossible to observe the response in the affected muscle. With the bipolar technique the density of current is located just where it is most needed and within a certain limit this current strength will not exert stimulation of neighboring groups.

Individual muscle stimulation is the method of choice when only a few muscles of an extremity are affected; if an entire extremity or a large group of muscles need treatment, it is permissible to use the group treatment.

Group Stimulation of Muscles.—This technique consists of applying two electrodes, as a rule of equal size to the opposite ends of an extremity; for instance, for the lower extremity one electrode may be applied to the sole of the foot, the other under the buttocks or under the sole of the other foot; for the upper extremity, the palm of the hand may be placed on one electrode, the other is applied in the interscapular space. A convenient way of group stimulation is by the galvanic-bath method (Chapter VIII). One may place the two hands separately, or one hand and one foot or each foot separately, in a basin of water connected to the source of a suitable low-frequency current.

The placing of the patient, gradual starting of the current and the necessity for watching of alternate contraction and relaxation is the same as in individual muscle stimulation. In the majority of cases, when the condition of muscles along an extremity is about the same, such as in weakness due to disuse, the surging current passing along the extremity results in a fairly even response of all muscle groups. It is almost uncanny to observe, how the different groups contract and relax alternately, once on the flexor and next on the extensor surface. This is due to the fact that the stronger stimulus always originates first from the negative pole and as in alternating-current stimulation first one end and then the other end of the extremity becomes negative, the most effective stimulus travels alternately from the two electrodes on the opposite ends of the extremity.

With muscles in fairly good condition, group stimulation of an extremity may be kept up from five to ten minutes, and repeated every day or every other day according to the prevailing condition. Stimulation by low-frequency currents may be preceded by or combined with longitudinal diathermy. In a limb which has been fully warmed up every muscle responds better and all local resorptive processes are accelerated. In after-treatment of fractures, in adhesions in the extremities following operations for infection or abdominal adhesions following laparotomy, combined diathermy and low-frequency stimulation is quite effective. (Page 243.)

Dangers of Application.—It was shown in animal experiments that cardiac fibrillation can be brought about by alternating low-frequency currents. In electrical shock cardiac fibrillation is often thought to be the main cause of death. Patients with myocardial weakness seem to be especially sensitive to low-frequency currents, while they can stand a high-frequency current (diathermy) through the heart with apparent benefit. Some unfortunate experiences on record should make it an invariable rule, never to apply low-frequency currents through the heart or with a technique which brings a considerable amount of current through the cardiac area.

The possibility of overexercising very weak muscles has been pointed out. Electrical muscle stimulation should never be employed to the neglect of such well indicated methods as rest and proper splinting in early stages of paralysis and muscle re-education and voluntary exercise in the stage of muscle and nerve regeneration. It should be considered at all times an adjunct to the other well established therapeutic measures and its administration in institutional work be entrusted only to technicians familiar with muscle physiology and pathology and fully instructed in proper technique.

STATIC ELECTRICITY

History.—Static electricity is the oldest form of electricity used in treatment. After the discovery of the first frictional electrical machine by Guericke, of Magdeburg, in 1670, and the Leyden jar by von Kleist, in 1745, it was used for the treatment of disorders of the nervous and muscular system by Jallabert, Priest and Abbé Nollet. Charcot used static sparks at his clinic in Paris for the treatment of nervous conditions. In America W. J. Morton advanced the subject by introducing, in addition to this method, the use of the sustained pulsatory discharge. The "Morton" wave and other modalities were further developed by the late William Benham Snow, of New York.

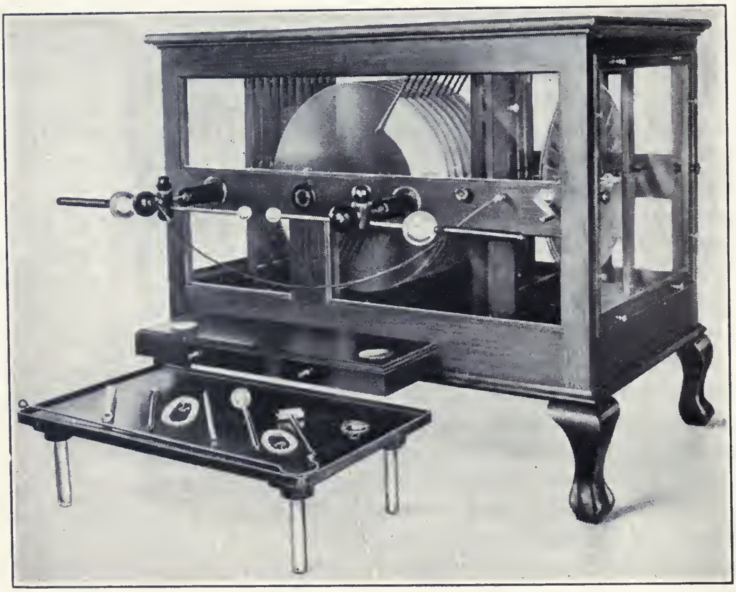

Fig. 133.—Static apparatus of the Holtz type. A separate "charger" is contained in the compartment on the right side.

The use of static electricity reached a peak at the beginning of the present century when the high voltage energy of static machines served also for activating the first roentgen-ray tubes and for the first d'Arsonval high-frequency circuits. The general design of static machines has not changed during the past thirty years. Because of the bulkiness of its apparatus and of the many newer forms of efficient electromedical currents, static electricity has fallen generally into disuse; therefore it will be presented in this volume very briefly as compared to previous editions.

Physics.—From a medicophysical viewpoint, static electricity represents a unique current. It is a unidirectional flow of electrons at the highest voltage: several thousand volts, but the lowest amperage: less than a milliampere. Static electricity is primarily produced by friction and the small charge of electrons is increased to a very high voltage by repeated self induction (influence) in a well insulated circuit.

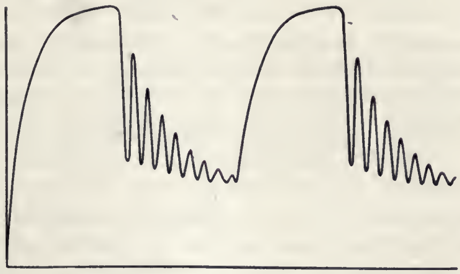

FIG. 134.—Graph of pulsatory discharge of static wave current.

The *static machine* consists of 6 to 12 pairs of large circular-glass plates mounted on a shaft and held in a large glass case. The outside current rotates the shaft. In the Holtz-Wimshurst type of machine first an initial electric charge is furnished by two smaller glass plates rotating against small tinsel brushes; the rotation of the large plates then "builds up" this charge so high that it sparks across two metal balls in front of the glass case. This unidirectional charge is then led off from either the positive or the negative terminal of the machine to the patient placed on an insulating platform, while the other terminal is "grounded."

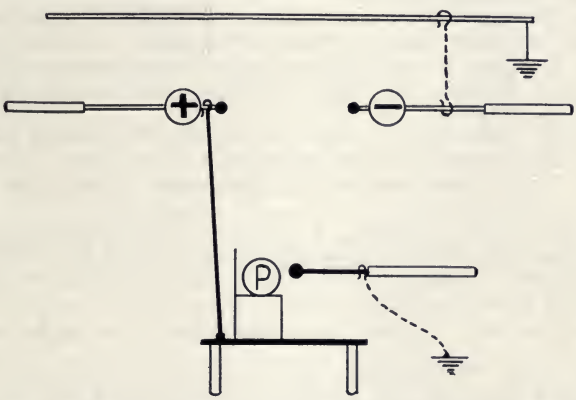

FIG. 135.—Diagram of "hook-up" for administering indirect static sparks.

Physicophysiological Effects.—The spark discharge across the terminals of the static machine represents a high-tension condenser discharge. (Fig. 134.) Such a pulsatory discharge at low frequency furnishes a repeated make-and-break of a unidirectional surging current; when applied to contractile tissues, it results in a response of nerves and muscles as caused by low-frequency currents; hence the presentation of static electricity as an appendix to this chapter.

In the *static wave current* the gradual opening of the spark gap brings about a series of rapid pulsatory discharges, which are conducted by a cord to a soft metal plate placed over the skin of the area to be treated. As a result of the comfortably regulated impulses, visible muscle contractions occur which help to improve circulation, reduce swelling and aid to overcome muscle spasm in acute traumatic and congestive conditions, such as myositis, sprains and selected forms of chronic arthritis. *Static sparks* consist of a sudden release of the static charge by approaching the patient with a grounded ball electrode; they also serve for decongestion and also for counterirritation in chronic inflammatory conditions.

Other forms of static treatments are the "static charge" or bath and the "static head breeze" in which the static charge is applied to the patient from the widely separated gap without any spark discharge; they may serve by "electrification" for treatment of nervous headache, and insomnia and other nervous states. In the "static brush discharge" a fan-like discharge is applied to acutely painful areas for gentle counterirritation and sedation. In competent hands the static apparatus is still a very useful and versatile piece of electrical equipment.

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CHAPTER X

HIGH-FREQUENCY CURRENTS AND APPARATUS

General Considerations. Experimental Demonstrations. Historical. Terminology. High-frequency Oscillations and Radio Waves. Physics of High-frequency Apparatus. Basic Principles. Vacuum Tube Apparatus. Controls of Vacuum Tube Apparatus. Spark-gap Apparatus. The Oudin Coil. Combination Apparatus. Requirements for Acceptance of Diathermy Apparatus. Protection Against Radio Interference. High-frequency Treatment Methods.

General Considerations.—A high-frequency current may be defined as an alternating current consisting of oscillations of a million or more per second. When applied to the human tissues, the extremely short impulse of each oscillation can barely cause any ionic movement and if it should this would be nullified by an impulse coming from the opposite direction. When an electric current flows through a conductor, the free electrons in the conductor are accelerated and acquire a "drift velocity" which is superimposed upon their irregular thermal motions. Through collision with the atoms in the conductor these electrons lose their kinetic energy and create thermal energy. Because of the absence of electrochemical reactions, there is no stimulation of sensory and motor nerves, in contrast to other forms of electricity.

There are two methods of high-frequency tissue heating in use at the present time. The older method known as conventional or long-wave diathermy employs oscillations of a frequency of about a million per second and is routinely applied through electrodes placed in direct contact with the skin. The newer method of short-wave diathermy employs oscillations from ten to a hundred million per second and is routinely applied through a spacing of air, glass or rubber, but may also be applied by direct contact. It is the spacing property of electrodes with its attendant advantages which is the outstanding feature of short-wave diathermy.

Historical.—The fundamental observation that the discharges from Leyden jar condensers were of oscillating character was made by the American physicist, Joseph Henry in 1842 and further elaborated in 1853 by William Thomson of England. Thomson concluded that the frequency of alternations might be thousands or even millions per second. In 1885 Hertz devised the means of producing and detecting electrical oscillations at a distance, thus proving the correctness of Maxwell's theory concerning the equal speed of propagation of all electromagnetic forces. Hertz' apparatus enabled Marconi to construct his first wireless sending set in 1896. Arsene d'Arsonval of Paris in 1892 was first to study the effect of high-frequency oscillations on the human body. In the United States Nicola Tesla in 1891 had observed the heating action of high-frequency currents. D'Arsonval reported the initial decrease and later the total absence of neuromuscular response when the frequency reached above 10,000 per second. He also observed the heat production in the body, but declared that it was an unpleasant accompanying sensation.

Zeynek, of Germany, collaborating with the Austrians, Preyss and Bernd, started in 1904, experiments on animals and first used the high-frequency current to treat gonorrheal arthritis in a man. They worked with an apparatus producing undamped oscillations through an electric arc, constructed by Poulsen, a Danish engineer, and called the method in 1907, "Thermopenetration." Nagelschmidt, in Berlin, also made experiments independently, named his method "transthermy," later changing it to "diathermy." American physicians took an early interest in diathermy, especially the late Frederic deKraft, and Edward C. Titus. With the increased interest in physical therapy after the first World War, the use of high-frequency spark-gap apparatus came to a high peak in the United States.

Apparatus producing higher frequencies by oscillating tubes was constructed by the French Gosset in 1924 and by the German Stiebock in 1925. The first animal experiments with very high-frequency oscillations were begun in 1924 by Schereschewsky of the United States Public Health Service. Schliephake of Germany in collaboration with the physicists Esau and Pätzold, in 1926 began biological work with short-wave oscillations up to 100 millions. Almost simultaneously Whitney, research director of the General Electric Company discovered that powerful tubes used for broadcasting caused general body heating and with the coöperation of Carpenter and Page inaugurated the use of short-wave diathermy for electropyrexia. After a large amount of experimental and clinical work, it appears well established that short-wave diathermy does not essentially differ in its clinical effects from conventional or long-wave diathermy. Hence the joint presentation of both forms of diathermy.

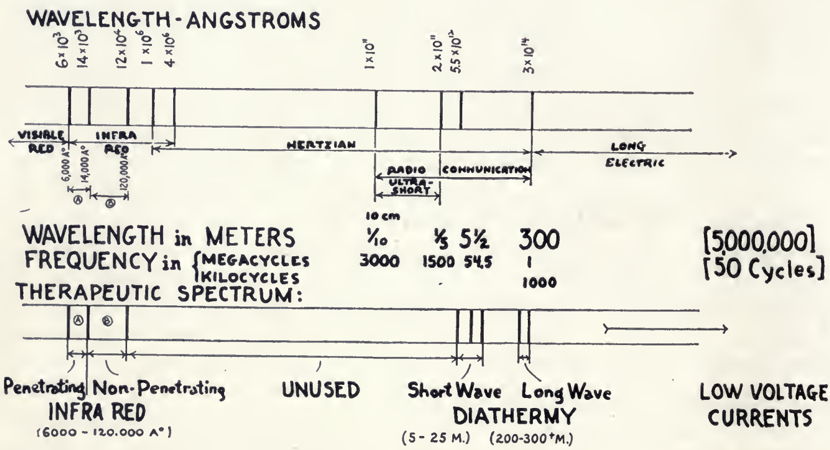

Fig. 136.—Wave lengths and wave frequencies in the infrared-high-frequency range of the electromagnetic spectrum.

High-frequency Oscillations and Radiowaves.—Electromagnetic waves (Chapter XV) all travel at the speed of light, at 186,000 miles or 300,000 kilometers per second in vacuum. The frequency of electromagnetic oscillations sent out by a spark-gap or oscillator tube generator is determined by the physical characteristics of the generating circuit. The generally accepted view of the propagation of electromagnetic oscillations is that they proceed in the form of waves and since all these waves travel at the same speed it is evident that the wave lengths of those of higher frequency oscillations are shorter, as indicated in Figure 137. In other words the higher the frequency of a certain form of electromagnetic energy, the shorter its wave-length. The unqualified use of the term "short-wave" to designate oscillations of higher frequency in therapy is confusing. There are relatively long and relatively short waves in every part of the electromagnetic spectrum, either in descending or ascending range—in the infrared, in the ultraviolet, in the roentgen-ray part—hence it would be incorrect to describe a form of electromagnetic energy as simply *short waves*.

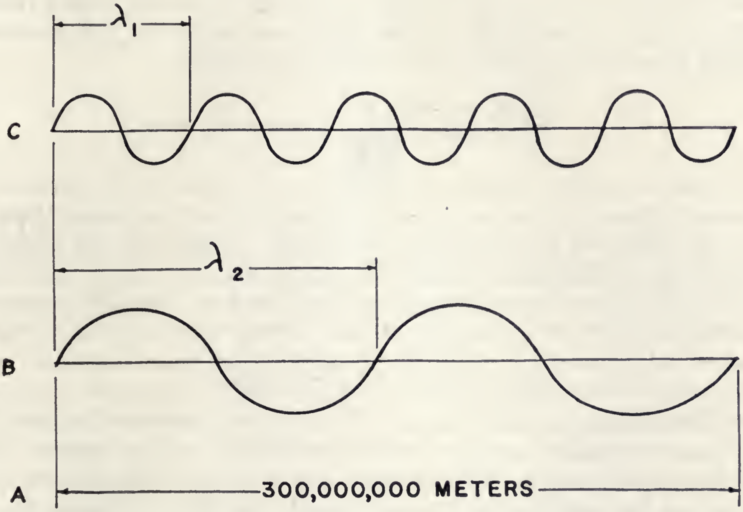

Fig. 137.—Graphic comparison of wave length and wave frequency. The base line, *A*, is a time unit during which electromagnetic waves, *B* and *C*, travel with the same speed (300 million meters per second), in order to cover the same distance in the same unit of time; the oscillation frequency of the longer waves, *B*, is less than that of the shorter waves, *C*. In other words, the shorter the wave length the greater is the frequency of oscillations.

The term "short-wave diathermy" has been accepted as the most comprehensive term for the newer form of high-frequency energy, while the logical term for the older method of contact plate treatment with 300 meter waves is "long-wave diathermy." Some of the authors still describe it as "conventional" diathermy, disregarding the fact that the newer generation of students is learning chiefly to use short-wave diathermy and hence will regard it as the "conventional" method of the present day.

For the differentiation of various electromagnetic waves the naming of their frequency serves to a large extent in radio broadcasting. In physical therapy the established custom is to describe these forms of energy by their wave length; this avoids the use of long figures.

The relation of wave length and frequency in the most frequently employed therapeutic electromagnetic oscillations is as follows:

Table 22.—Wave Length (Meters) and Wave Frequency (Cycles per Second)

Frequency	*Wave length*	*Term*
1 million (1 megacycle)	300 meters	Long-wave diathermy
10 millions (10 megacycles)	30 meters	Short-wave diathermy
100 millions (100 megacycles)	3 meters	Short-wave diathermy
300 millions (300 megacycles)	1 meter	Microwaves

The wave length is obtained through a simple equation by dividing the distance covered in one second by the number of oscillations occurring in one second.

$$\text{Wave length} = \frac{\text{Speed of light p. s.}}{\text{Number of oscillations p. s.}}$$

The generally accepted standard of measurement is the metric system and hence all wave lengths are calculated in meters. Wave length can be measured by especially constructed wave meters. If by such a wave meter the length of a wave is determined at 10 meters, the number of oscillations per second can be calculated according to the formula by dividing the speed of light by the number of meters.

$$\frac{\text{300,000,000 meters}}{\text{10 meters}} = \text{30,000,000 oscillations}$$

The electromagnetic waves of short-wave diathermy are generated by the same physical means as those of the short-wave broadcast band and are as a matter of fact identical with them. However, for therapeutic purposes the oscillations produced are not transferred to an "open circuit" through the aerial and ground connections, but to a "closed" or treatment circuit which can be considered as two aerials, between which the part to be treated is placed. Actually the treatment plates are these two aerials; when paired in this manner they form a condenser. The part to be treated is introduced into the electric or condenser field between the plates; this field conveys regular impulses to the particles of the substance. When these impulses enter the body tissues, they become a high-frequency current just as the oscillations of conventional or long-wave diathermy.

PHYSICS OF HIGH-FREQUENCY APPARATUS

Basic Principles.—In order to produce oscillations of sufficiently high frequency and power to heat the human tissues, two essential changes have to be effected in the commercial alternating current which serves as the source of all high-frequency electricity: (1) the voltage must be increased; this is done by a step-up transformer; (2) the frequency must be increased; this is done by an "oscillating circuit" as described in Chapter III. Such a circuit consists of condenser, inductance and a spark gap in the spark gap apparatus and of condenser, inductance and oscillating tube in the vacuum tube type apparatus.

The important property of an oscillator circuit, in a tube as well as in a spark-gap apparatus, is that *any desired wave length may be obtained by suitable variation of the physical characteristics of the circuit.* The frequency is determined by the *capacity* of the circuit, depending on the surface area and number of the plates of the condenser and the *inductance,* depending on the diameter and number of turns in the coil. Decrease of capacity or self-induction or both together result in increasing the frequency or decreasing the wave length. A given combination of capacity and inductance produces a definite wave length, for instance, 12 meters; if an alternative wave length of 24 meters is desired, than a separate circuit of different capacity and inductance must be incorporated in the apparatus, and this circuit must be switched on, in place of the other.

There are definite physical limitations to the production of therapeutically efficient oscillations of very short-wave length, due to the fact that at shorter wave lengths the connections between the parts of the oscillating circuit, such as the cables also take up some part of the oscillating energy. The lower limit for the generation of short waves of an output of more than a few watts is at present between 3 and 4 meters.

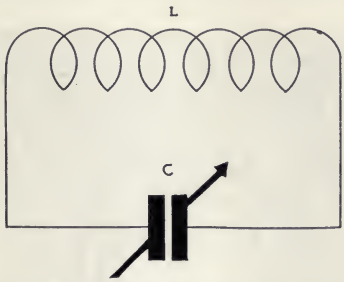

FIG. 138.—Showing a typical oscillator circuit consisting of an inductance (coil, *L*) and capacity (condenser, *C*). This circuit will produce an oscillating current of a given frequency depending on the electrical values of *L* and *C*. When the condenser is charged by a source of current and allowed to discharge, such a circuit will be resonant to a given frequency. In order to produce different frequencies the value of *L* or *C*, or both, must be changed.

VACUUM-TUBE APPARATUS

The three principal divisions of the vacuum-tube apparatus are: (1) the power supply, (2) the oscillator, (3) the output or patient's circuit. The details of these circuits and the frequencies produced vary in different types of apparatus. We will present one of the simplest and most typical constructions. The construction and the operation of the rectifier and oscillator tubes employed in these circuits have been already described in Chapter III.

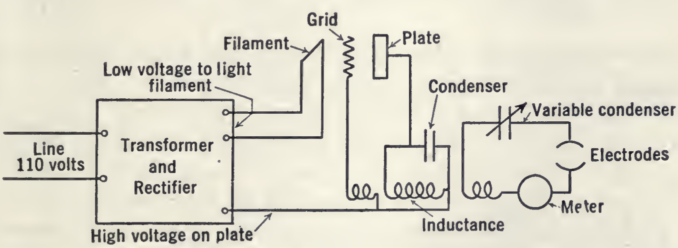

FIG. 139.—Schematic diagram of typical oscillator circuit with vacuum tube. (Hemingway, courtesy of Archives of Physical Therapy.)

Power Supply Circuit.—The function of this circuit is to provide a source of low voltage alternating current to light the filaments of the oscillator tubes, and a source of high-voltage direct current for the plates of these tubes. The power supply circuit consists of several power transformers (with step-up and step-down secondary coil windings to provide the required voltages), a pair of rectifier tubes, and, sometimes, a filtering circuit.

The line voltage is fed to the primary windings of the transformers. The high-voltage transformer usually has a choke coil in its primary circuit which controls the output of this device and thereby controls the output of the machine. Separate step-down secondary windings provide low-voltage alternating current to light the filaments of the rectifier and oscillator tubes. The usual type of mercury vapor rectifiers require $2\frac{1}{2}$ volts to light their filaments. The average oscillator tubes require 10 volts of filament voltage. A regulating device and meter may be provided to keep the oscillator filament voltage constant, thereby prolonging the life of the tubes.

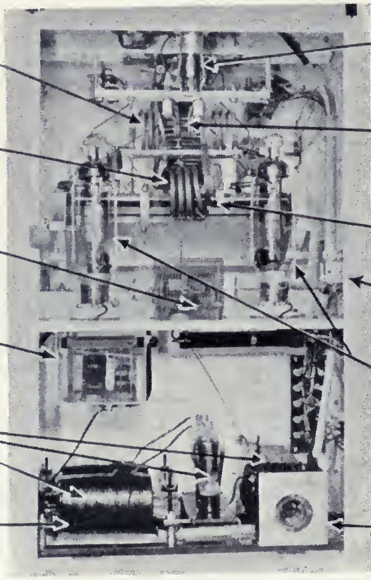

FIG. 140.—Interior view of short-wave apparatus, furnishing a 6 to 8 meter circuit for condenser field treatment (pads) and a 20 meter circuit for electromagnetic field (inductance coil) treatments. (Courtesy of the Liebel-Flarsheim Company.)

The high-voltage alternating current from the power transformer is fed to the plates of the 2 mercury-vapor rectifier tubes. Each tube passes current during that half of the alternating current cycle when its plate is positively charged. With two tubes operating a pulsating unidirectional current of high voltage is allowed to pass. This current is rough but has definite polarity. Some machines provide an additional filtering circuit consisting of a smoothing choke coil and a large capacity condenser. This filters the rough unidirectional current to provide a smooth high-voltage direct current. Such a smooth current applied to the oscillator tubes improves the frequency stability of the apparatus.

The Oscillator Circuit.—This produces the high-frequency oscillations. It consists of a grid circuit, a pair of oscillator tubes and a plate circuit. The grid circuit is a coil and condenser whose values of capacity and inductance have been fixed to determine the frequency desired from the machine. When this circuit is charged with electrical energy it provides a source of voltage at the grids of the oscillator tubes. One grid will be charged positive when the other grid is negative and the charge is reversed during the next high-frequency cycle. Thus many million times a second the electrical charge at grids of the tubes changes (Fig. 141).

The *oscillator tubes* under the influence of the charge of the high-voltage direct current supplied at their plates produce a high voltage very rapidly alternating (or high-frequency) current. The filaments provide an electron path to the plates, over which the current can flow. The positively charged plates of both tubes tend to draw current over this path. But the grid of one of the tubes is negatively charged at any given moment and current can flow through the plate circuit only from the other tube. At the next

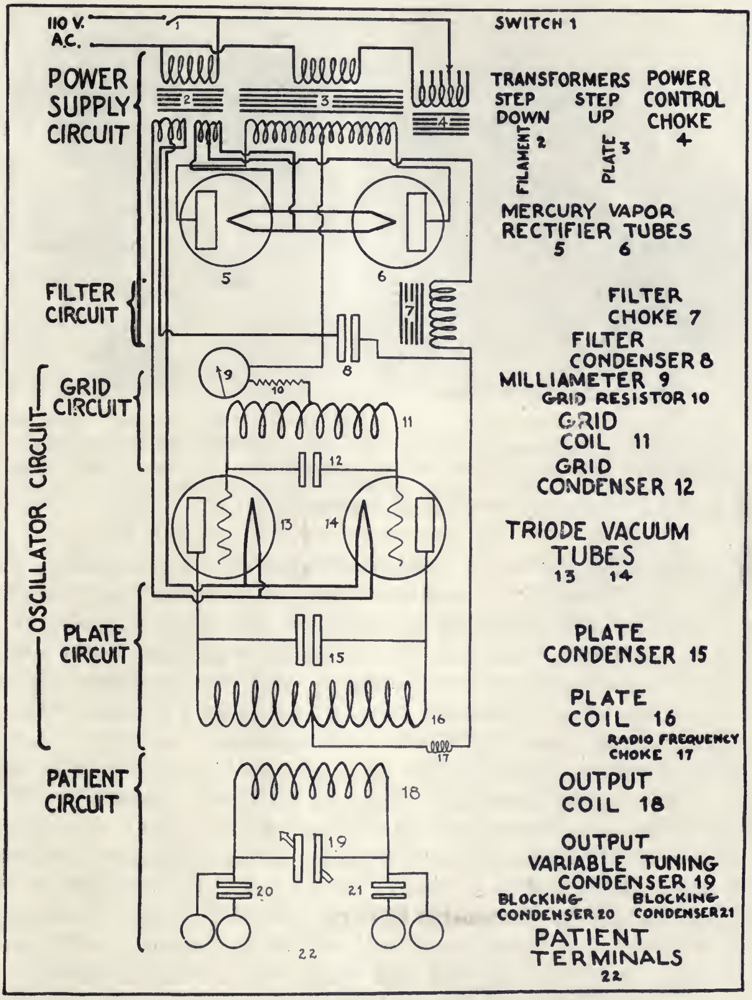

FIG. 141.—Diagram of 4-tube oscillator circuit.

half cycle this grid becomes positive, allowing current to flow through this tube. Thus a changing direction of current, first from the plate of one tube and then from the other, is set up in the plate circuit.

The *plate circuit*, or tank circuit, is made up of capacity and inductance. Its frequency of operation is fixed at the same point as that of the grid circuit by the use of equivalent condenser and coil values. These two circuits being resonant to the same frequency, mutually energize each other to maintain oscillation at this frequency. The changing direction of current in the plate circuit sets up an electromagnetic field which cuts across the grid circuit and sets up a small current in it. This current serves to charge the grids of the oscillator tubes and thereby maintain high-frequency alternations in the plate circuit. This same electromagnetic field excites an auxiliary circuit by induction. This circuit, the output or patient's circuit also is resonant.

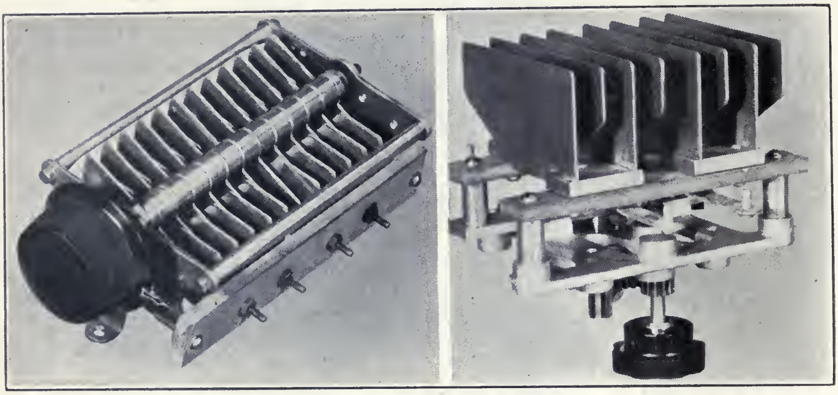

FIG. 142.—Two typical condensers used for tuning short-wave output. Left condenser varies capacity by rotary motion of the moving plates. The right condenser varies capacity by transverse linear motion of moving plates. The advantage of the latter type is that as the capacity diminishes spacing increases and this prevents spark-over from the consequent increasing voltage. (Courtesy of the Peerless Laboratories, Inc.)

The Patient's Circuit.—This consists of inductance and capacity. Either or both may be variable in order to "tune" this circuit, but usually the coil is fixed and the condenser is variable. The tuning device of most short-wave diathermy machines is this variable condenser. It serves to bring the patient's circuit into resonance with the oscillator frequency, just as one resonates a radio set when he tunes in a station. When the condenser is finally tuned it allows the maximum transfer of inductive energy from the oscillator to the patient. As one slightly detunes the condenser less energy is extracted from the oscillator circuit.

In transferring the energy from the generator or tank circuit to the patient or secondary circuit, the frequency of the secondary circuit must be the same as that of the primary circuit; that is, the product of the capacity and the inductance must be equal in both circuits. If this requirement is fulfilled, the secondary circuit will be in resonance with the generator circuit, and the machine will deliver its maximum output. This condition of resonance is analogous to the musical resonance of the tuning fork, which responds only if its own pitch is reached. The thickness of the objects to be treated in the patient's circuit, their dielectric constants, the distance of the electrodes (condensers) from the surface, and the size of the electrodes determine the capacity of the secondary circuit and necessitate careful "tuning" of this circuit with the generating circuit.

A *milliammeter* is placed in short-wave apparatus usually in the plate circuit of the oscillator. It serves primarily as an indicator that electrical energy is passing. The removal of energy from the oscillator to the patient causes a greater current drain which is noted by the rise in the meter. The meter will also indicate that at a certain position of the controls—when the patient's circuit is "tuned" to the main oscillator circuit—there is a maximal flow of energy in the treatment field. But in contrast to the meter in long-wave apparatus it does *not* register the amount of energy passing through the patient.

Vacuum-tube apparatus produces oscillations of frequency from 10 to 100 millions per second. These oscillations are "*undamped*" and have a uniform amplitude in contrast to the damped oscillations of a spark-gap apparatus. When applied to the human tissues, both damped and undamped oscillations produce heat. Vacuum-tube apparatus operates silently and needs no adjustment, except the replacement of worn-out tubes.

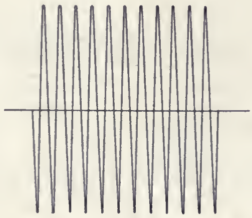

FIG. 143.—Graph of undamped, sustained high-frequency current.

The *tubes* are the heart of the short-wave apparatus and on their proper function depends the efficient output of the apparatus. Tubes are not made by manufacturers of apparatus, but are received by them under a guarantee that they are free from electrical and mechanical defects. Well made and properly operated tubes have a normal life cycle from five hundred to one thousand hours and at the end of this period do not burn out as a rule, but gradually decrease in output. A defective tube will result in the dropping off in power of the apparatus; it will also cause overheating of another tube in the circuit. A crack in the glass of a tube will result in the admission of air and destruction of the tube.

Most American built short-wave diathermy equipment employs tubes whose filaments are "thoriated" or treated with thorium for improved electron emission. This improves the emission efficiency enormously and also adds to the useful life of tubes. It is, however, of paramount importance that filaments be maintained at a constant temperature (*i. e.*, voltage) or they will quickly become paralyzed and lose all output. Most well constructed apparatus contain a device to determine at any time whether the filament voltage is proper and also may provide a danger reading on the voltage indicator. Other safety features are automatic overload relays or audible warning signals when the safe tube current limit is exceeded. Modern tubes are of the air or self-cooled variety and do not require forced cooling. However, in the interior of some apparatus ventilation is poor, so frequently a fan is provided to keep the air circulating and prevent overheating of the various parts.

Two-tube Short-wave Circuits.—In contrast to the typical four-tube arrangement described, some of the short-wave diathermy machines in use today contain only two tubes. These tubes are connected directly to the secondary of the main power transformer and are supplied with high-voltage alternating current. In order to operate as oscillators, these tubes require high-voltage direct current to flow through their grid and plate circuits. Therefore self-rectification takes place in these tubes just as in regular rectifier tubes and a source of intermittent direct current is produced. This direct current source is then utilized by the tubes for oscillation. Self-rectification dissipates considerable power in the tubes, hence these tubes are usually larger in size than those used for oscillation alone. The high-frequency energy which self-rectified tubes deliver is modulated by the rise and fall in the rectified current at a rate of about 120 times a second. Therefore the power output for a given voltage is less than that for straight oscillator tubes.

Controls of Vacuum Tube Apparatus.—The controls and steps in operating the average short-wave diathermy apparatus are as follows:

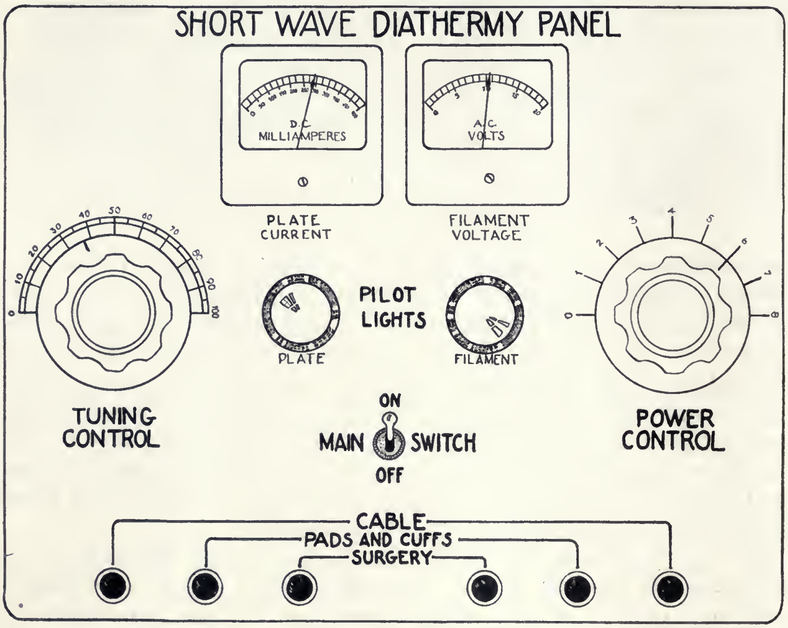

FIG. 144.—Controls on panel of short-wave diathermy apparatus.

The Main Switch of Power Inlet provides the supply current flow. It serves first for the warming up of the filament (cathode) in the vacuum tubes. It takes a few seconds for this heating. The filament should always be allowed to heat up a few seconds before the plate voltage control is turned on.

The Current Output Control is a controlling device with numbered steps or an indicator arrow; it enables the turning on of an increasing amount of supply current to the oscillator tubes according to the conditions of the patient's circuit.

The Coupling or Tuning Device controls the energy transfer from the oscillating or tank circuit to the patient's circuit. The maximum excursion of the meter needle shows that in a given set up there is a maximum energy flow and full resonance.

SPARK-GAP APPARATUS

Figure 145 shows a diagram of the typical parts of a spark-gap apparatus and the graph of the current produced in each. The incoming alternating current supply passes through a choke coil—which regulates the amount of current drawn—on to the transformer which consists of insulated strands of wire wound on a core made up of thin plates of electromagnetic steel; it steps up the 110-volt current to 2000 volts or more. No change in the number of alternations or frequency takes place in the transformer.

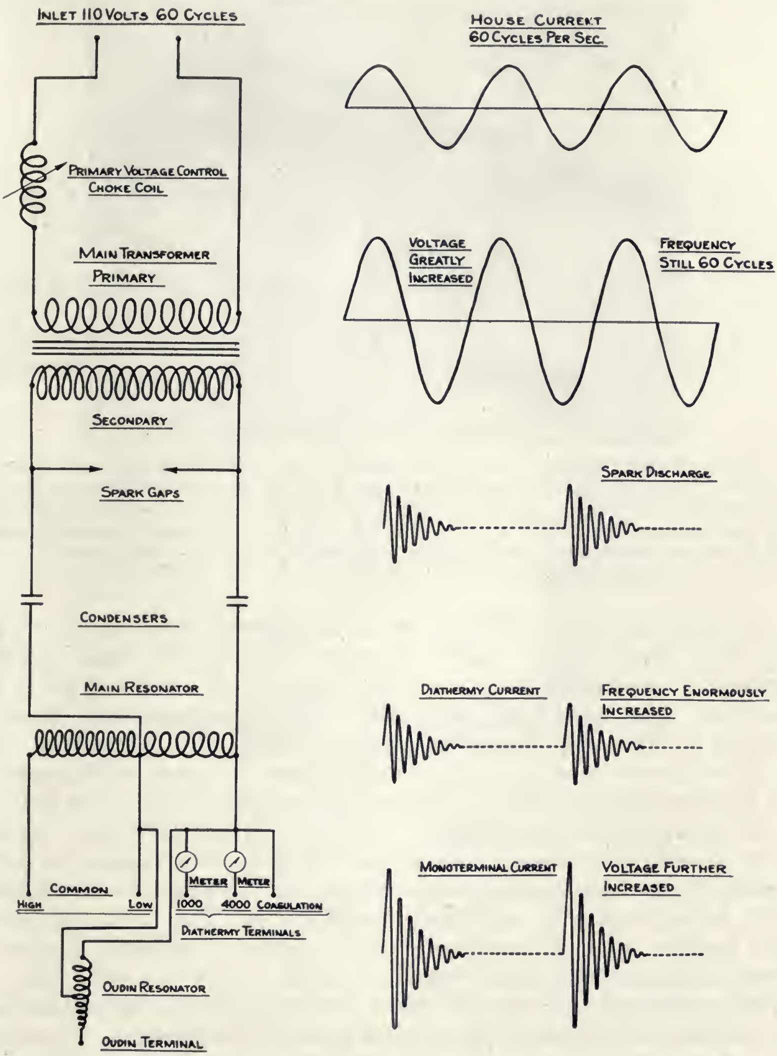

Fig. 145.—Diagram of circuits and oscillations produced in diathermy apparatus of spark-gap type.

The high-voltage current from the secondary side of the transformer acts on the *high-frequency circuit*, consisting of a spark gap, a condenser and the resonator. The *condenser* in most machines consists of plates composed of alternate sheets of metal and mica (Fig. 8) except in very high-voltage apparatus where Leyden jars are employed. The condenser works like a storage battery except that the electricity is not stored by a chemical but by an electrostatic process. If the condenser is filled to capacity and the contact points of the spark gap are brought within a suitable distance, the condenser empties itself by an oscillatory discharge. The discharge period of the condenser takes about $\frac{1}{1000}$ second and as soon as the charge is dissipated the condenser is charged again.

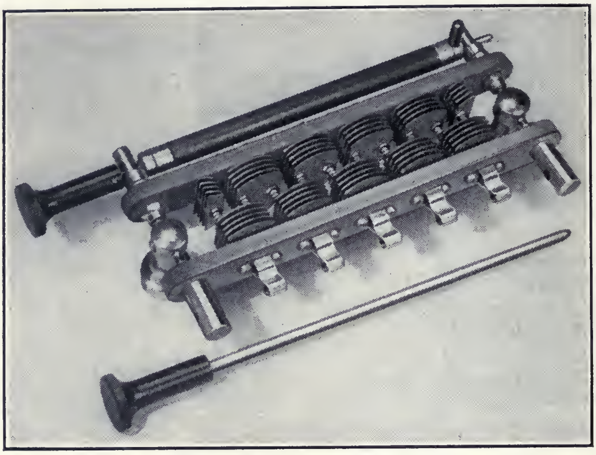

FIG. 146.—Typical multiple spark gap as used in large cabinet type diathermy apparatus. A short-circuiting rod, shown lying in front of the gap, may be inserted from the left to short circuit as many gap sections as desired when very fine desiccation, for example, is to be done. Each gap section is individually adjustable initially, and the entire gap is ordinarily manipulated by the master control. It is mounted on blocks of high insulating material such as lava, and covered by a protective shock-proof guard.

The *spark gap* consists of two or more tungsten metal discs insulated from each other. As the spark discharge heats up the discs, cooling is provided by mounting them on metal blocks with radiating fins. It is important that spark gaps and their cooling arrangement should be mounted so that they cannot be touched accidentally, because this may lead to a burn or electric shock. The hissing noise heard in the operation of a spark-gap apparatus is normal to the function of the spark gap.

The inductance in spark-gap apparatus is furnished by the *resonator* which consists of two coils: the d'Arsonval coil or the primary is formed by a few turns of heavy wire and is wound over the Tesla coil or secondary, which contains many turns of small magnet wire. The Tesla coil is essentially another step-up transformer which serves to increase the voltage of the high-frequency oscillations.

The oscillations from the resonator are conducted to the patient from the outlets or terminals on the control panel of the machine. The oscillations of the long-wave spark-gap machine are not continuous but occur in separate oscillation periods, each consisting of a series of rapidly decreasing oscillation trains. Such oscillations are known as "damped" oscillations and their frequency varies from 500,000 to 2,000,000 per second.

The *milliammeter* in spark-gap machines is either of the hot wire or of the thermocouple type. It is placed in series with one of the leads to the patient. It indicates the quantity of current passing in the circuit of the patient, but not the heat developed in the tissues. It is possible, if the meter is out of order, to have current passing through the patient without the meter indicating any current flow. A defective meter usually manifests itself by sparking within the meter case and this causes the patient to experience a faradic sensation.

FIG. 147.—Graph of damped intermittent high-frequency current.

The scale of the meter usually reads from 100 to 2500 milliamperes or more. In order to provide accurate reading, ordinarily a double scale is provided, one for currents from 100 to 1000 (low reading), the other for currents from 2500 or 4000 (high reading). In some apparatus, in order to protect the meter in case of short circuit caused by unexpected contact of cord tips or other accidents, a fuse is inserted in the patient's circuit. One should learn where this fuse is located and how it can be replaced.

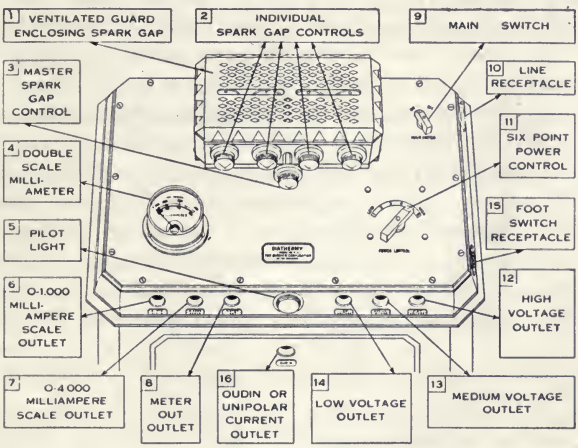

FIG. 148.—Diagram of control board of cabinet type diathermy apparatus. (Courtesy of the Burdick Corporation.)

The zero position of the needle of the hot wire type of milliammeter setting is subject to slight change with the room temperature, due to expansion or contraction of the wire. A regulating device enables the resetting of the needle at zero point.

Operating the Spark-gap Apparatus.—The supply current is turned on through the main switch and the amount drawn is regulated by the choke coil. The high-frequency oscillations are regulated by the spark-gap control. At its lowest point no oscillations occur and there is no current flow in the patient's circuit.

The Oudin Coil.—Most spark gap machines contain a third coil or solenoid, first constructed by Oudin and hence known as the Oudin coil or Oudin resonator. It consists of a coil of fine wire connected to a lead off from the resonator. The Oudin coil constitutes an additional step-up transformer. It produces a high-voltage modification of the high-frequency current known as the Oudin current. This current is led off from a single terminal of the diathermy apparatus known as the Oudin (monoterminal) outlet. The voltage of the Oudin current is so high that when a glass vacuum or condenser electrode is attached to the Oudin terminal, it will become powerfully charged and on approaching the patient's skin it discharges in the form of a fine "effleuve" or coarse sparks. The output of the Oudin circuit is also regulated through the double control of the choke coil and the spark gap.

Combination Apparatus.—Either the spark gap or the tube type of diathermy machine can be used for medical or surgical purposes. There is also available specially constructed apparatus, which combines the features of one type of apparatus with those of the other one, exclusively for surgical purposes. Combinations are arranged: (1) By placing a spark gap and a tube machine in the same cabinet; the former serves for coagulation and desiccation, the second for cutting; (2) by arranging a spark-gap machine with various spark frequencies; high-spark frequency for cutting and low-spark frequency for desiccation and coagulation. (Chapter XIII.)

It is also possible to construct spark-gap apparatus to produce oscillations of much higher frequency, and these can then be employed for treatment techniques just as those of the tube apparatus for short-wave diathermy. Because of the higher expense of construction this type of spark-gap apparatus is at present not manufactured in the United States.

Requirements for Acceptance of Diathermy Apparatus.—In order to insure mechanical efficiency of a diathermy apparatus and its ability to produce deep heat within the body tissues certain requirements have to be fulfilled. Before placing any apparatus on its list of accepted apparatus the Council on Physical Medicine of the American Medical Association requires the submission of satisfactory physical and therapeutic evidence of the performance of the apparatus. Physical data required by the Council[1] before acceptance of any short-wave diathermy apparatus are:

"1. Power output and input. The power output may be determined by a lamp load or by a calorimeter.

"2. Transformer final temperature and temperature at various levels inside the cabinet taken after a two-hour run at full load.

"3. Patent number or copy of license agreement.

"4. Evidence indicating that radio interference has been reduced to a minimum by inclusion of filters or other devices for this purpose.

"5. A report from the Underwriter's Laboratories or assurances that the parts used in construction meet the Underwriter's requirements.

"6. Evidence to substantiate the heating ability of the unit. This consists of six tests made for each treatment technique for which claims are made in the advertising matter or descriptive literature of the firm. Deep muscle temperatures are taken by thermocouples. A final temperature of 103° to 104° F. in the deep muscle of the thigh is considered ample by the Council."

Two physical tests are performed on each short-wave unit submitted for the Council's consideration. The one test determines the maximum power output of the unit, and the other the temperature rise of the transformer.

According to Mittelmann and Holmquest[5] misleading use of the term output power, *i. e.*, the total available output of a generator is responsible for false conclusions regarding the heating effectiveness of short-wave diathermy generators. The voltage used in clinical practice is relatively small in comparison to output power, because the total power delivered by the apparatus is divided into two components: the energy absorbed by the patient and the radiation losses. Both are subject to wide variation according to technique of application, electrodes, air space, etc., besides current flow and its frequency of oscillation. Measurement of the actual power absorbed by the patient is possible by means of a direct reading wattmeter. A properly designed generator having a maximal output of 200 watts will provide sufficient power even for fever therapy. Holmquest and Mittelmann[4] have described a phantom which can be used to determine the useful output of short-wave diathermy apparatus.

Protection Against Radio Interference by Electrical Apparatus.—Installation of radio apparatus in homes has become universal, and every physician operating a high-frequency, roentgen-ray or static machine may be reminded by his neighbors of its disturbing influence on radio reception. According to Williams[7] the most prominent offenders in our armamentarium are the various medical and surgical diathermy machines, particularly the new short-wave diathermy and artificial fever devices. Important activities of the Naval Research Laboratory at Washington, D. C., were subjected to interference so serious as to stop the work completely. Eventually, after great trouble and expense, the disturbance was traced to therapeutic equipment. The first disturbing instrument located was a diathermy unit in a hospital at Cambridge, Mass.[3]

Since interference by electrical apparatus can be reduced to a minimum, physicians should have knowledge of the means of doing so. Low-voltage and low-frequency electrical apparatus cause little trouble. Occasionally the make and break of the circuit may cause some disturbance to get back into the power line and produce clicks or thumps. The motors driving such low-frequency generators may cause interference due to sparking at the brushes, just as any other motor, such as a fan, would.

High-voltage and high-frequency currents can surge back through the power supply into the power line, or they may actually radiate into space as radio waves. Any high-frequency apparatus is capable of radiation if its power is fed into an open electrical circuit. Long-wave energy requires long wires for efficient radiation, therefore the usual length of cords used on conventional diathermy machines radiate little. Such energy as is radiated is soon dissipated as a ground wave transmission at these frequencies. Higher frequencies used in short-wave machines require shorter wire from which to radiate efficiently, and therefore a considerable amount of energy may leave the conducting leads. Such energy as leaves the wire is more likely to travel far, by virtue of refraction and reflection by the stratospheric Kennelly-Heaviside layer of ionized particles high over the earth's surface. A glance at the chart by Schlesinger[6] will reveal how much radiated energy can interfere with many forms of radio services. Poorly designed and unstable apparatus are a further cause of radio disturbances.

Two remedies have been proposed to eliminate radio interference by high-frequency apparatus: one is screening of short-wave diathermy machines, the other allocation of a special wave band for therapeutic purposes. Elimination of radio interference by protection against leakage waves consists of full metallic shielding of the rooms in which apparatus is housed and of grounding the metal sheath in an approved manner. It is an expensive procedure and has not proven successful.

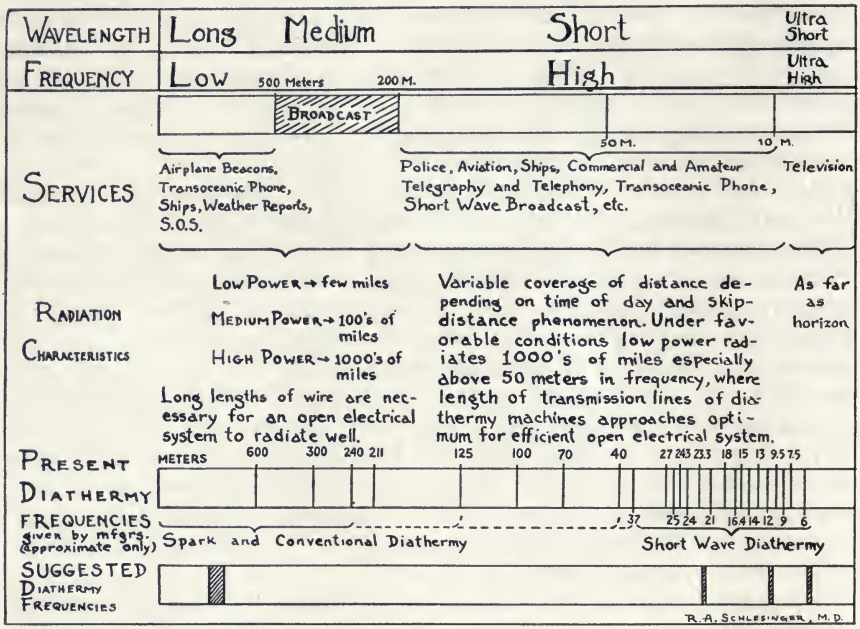

FIG. 149.—High-frequency oscillations by diathermy apparatus in relation to radio interference. (Courtesy of Dr. R. A. Schlesinger and Medical Record.)

The Federal Communications Commission[3] has assigned the frequencies of 13.66, 27.00 and 40.98 megacycles, corresponding with wave-lengths of about 22, 11 and 7.32 meters in the radio spectrum for the use of diathermy apparatus in order that a minimum of radio interference is caused to other services. It requires a design of apparatus which in its center wave-lengths does not vary beyond ±0.05 per cent in the 22 and 7 meter waves and ±0.5 per cent in the 11 meter waves. In the opinion of manufacturers this fairly wide band allocation will enable the supplying of non-crystal controlled short-wave apparatus that will not be any more difficult to service than those presently used and whose manufacturing costs will not be greatly in excess of the type heretofore supplied. It also enables the adjustment of many of the older machines to the now standard frequencies. It seems only fair to expect that the Commission will allow a reasonable transition period during which physicians and hospitals can have the requested changes made.

HIGH-FREQUENCY TREATMENT METHODS

High-frequency currents are either applied for treatment within physiological toleration of tissues: medical high frequency or diathermy, or for destruction of new growths and diseased tissues, surgical diathermy or electrosurgery according to the now generally accepted terminology.

The two forms of medical high-frequency application are short-wave diathermy and long-wave diathermy. They are principally used for tissue heating within physiological toleration. For this purpose three forms of technique are available:

1. Direct contact heating. The metal electrodes charged by the current are placed in direct contact to the skin or mucous membrane. This is the classical method for long-wave diathermy, but with certain provision can also be used for short-wave diathermy.
2. Electric or condenser field heating: the electrodes are separated from the skin or mucous membrane by an insulating layer of air, glass or rubber.
3. Electromagnetic field heating: an insulated cable in the form of a coil or loop is wound around the part or is held against it in a treatment drum.

The electric and electromagnetic field methods are employed with short-wave diathermy.

The energy output of a long-wave spark gap diathermy apparatus may be used medically also for two special forms of applications: (1) Autocondensation, where one electrode is applied directly to the skin, another held separated from it by a dielectric of hard rubber or a thick mattress. (2) Oudin treatment or monopolar high frequency where the current, being further stepped up by a transformer, is led from a single high voltage terminal to a glass electrode and thence to the body.

Table 23 gives a condensed presentation of present day high-frequency methods.

TABLE 23.—HIGH-FREQUENCY TREATMENT METHODS

	Medical Methods	
	Technique	*Effect*
Short-wave diathermy	Electric field heating	Depth heating of all tissues
	Electromagnetic field heating	Heating chiefly vascular tissues
	Direct metal contact	Heating more localized
Long-wave diathermy	Direct metal contact	Heating of all tissues
	Autocondensation	Mild general heating, local heating under contact electrode
	Oudin treatment	Mild counterirritation; surface heating
	Surgical Methods	
Electrodesiccation	Single electrode from Oudin terminal of spark gap	Drying of small growths; epilation
Electrocoagulation	One active and one dispersive electrode	Extensive coagulation; sealing of small blood-vessels
	Two active (biterminal electrodes)	Coagulation sharply localized between electrode points
Electrosurgical cutting	One active, one dispersive electrode from terminals of tube machine	Cutting of tissues with minimal coagulation: sealing of capillaries

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4. Holmquest, H. J., and Mittelmann, E.: Physical Method of Determining Useful Output of Short Wave Diathermy Apparatus, Quart. Bull. Northwest. Univ. Med. School, **15**, 255–262, 1941.
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6. Schlesinger, R. A.: Diathermy Apparatus in Relation to Radio Interference, Med. Rec., **149**, 309–312, 1939.
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CHAPTER XI

MEDICAL DIATHERMY

General Considerations. Experimental Demonstrations. Thermal Effect. Physiological Effects. Clinical Uses of Diathermy. Short-wave *vs.* Long-wave Diathermy. Contraindication and Dangers. General Technique. Technique of Short-wave Diathermy. Technique of Long-wave Diathermy. Regional Technique of Diathermy. Safety Rules in All Diathermy Treatments. Special Precautions With Short-wave Diathermy. Special Techniques of Long-wave Diathermy. General Diathermy. Autocondensation. Monoterminal High-frequency (Oudin) Treatment —Combination of Low-frequency Currents With Diathermy.

General Considerations.—The principal physical effect of high-frequency treatment is the heating of the human tissues. The production of heat is not a specific property of the high-frequency current, for any electrical current, in accordance with Joule's laws, will heat tissues. Low-frequency currents are not suitable for tissue heating because their electrolytic or polarity effects will bring about tissue destruction at a strength which would cause appreciable heating. Radiant sources of heating (heat lamps and infrared generators) as well as conductive sources of heating (hot-water bottles and electric pads) produce chiefly superficial heating, as shown by the skin redness due to dilatation of the capillaries. It is also evident that in any "external" heating through the skin, increased circulation and perspiration will tend to disperse some of the heat and preclude deeper penetration. It is furthermore difficult, if not impossible, to cause intensive heating of deeper parts by conductive heating without overheating the skin. The experimental proofs of the penetrating heating by diathermy and the clinical result produced by it have established high-frequency tissue heating as one of the most important methods in physical medicine.

Experimental Demonstrations.—Three classical experiments have been employed with long-wave diathermy apparatus for many years to demonstrate the basic physical effect of a high-frequency current upon conductors and its difference from that of a low-frequency current.

(*a*) Water Experiment. *The high-frequency current exerts no electrolytic or electrochemical effect.* The tips of two conducting cords leading from the terminals are placed about 2 inches apart in the flat vessel containing tap water. Turning on a fair amount of current, the excursion of the meter needle will show passage of the current, but no bubbles appear around either cord tip, no matter how long the current flows. If a few pinches of salt are added to the water the meter will rise further, showing the passage of more current due to increased conductivity, but there still will be no formation of gas bubbles.

(*b*) Light Bulb Experiment. *The high-frequency current exerts heating effects on the body without causing neuromuscular stimulation.* A person holds a cylindrical electrode in each hand; the base of one cylinder is connected to one terminal of the high-frequency machine, the base of the other to an electric light bulb (socket-testing device). The latter is then connected to the second terminal. As soon as the current is turned on the lamp lights up, yet the individual through whom the current passes perceives practically no sensation and there is no muscular twitch.

(*c*) Wrist Experiment. *The maximum heat effect of a high-frequency current occurs along the shortest path of the current, where the density is greatest.* A person grips one cylindrical electrode in each hand holding the wrists straight. With 500 milliamperes of current turned on the heat is felt about equally around the wrist. If the subject flexes his wrists, immediately more heat is felt at the volar surface, while if he extends them more heat is felt on the dorsal surface.

THERMAL EFFECT OF DIATHERMY

The penetrative effect of high-frequency electrical energy extends from electrode to electrode through the human tissues and has become the standard method for deeper tissue heating in the body. The basic laws for heating of conductors are those known as Joule's Laws: (*a*) The heat produced is directly proportional to the square of the current strength. (*b*) The heat produced is directly proportional to the resistance of the conductor. (*c*) The heat produced is directly proportional to the time during which the current flows. The actual heating of tissues depends on the number of calories supplied to the tissues per second by the high-frequency current. This can be expressed as a power unit; 1 watt equals 0.239 calories per second (Mittelmann, Osborne and Coulter).[19] A quantitative measure of treatment is obtained by measuring the actual power absorbed by the patient. Measurement by these authors showed that in local treatments absorption of 80 watts can produce temperature elevations of 8° to 10° F., which corresponds to final temperatures of approximately 106° and 107° F. In fever treatments by electromagnetic induction the average rise of temperature is about 1° F. each fifteen minutes with the absorbed power not exceeding 160 watts in a subject of average weight.

The classical investigations of Binger and Christie,[1] with long-wave diathermy at the Rockefeller Institute for Medical Research, showed that: (1) The heat gradient of the body is reversed during diathermy so that heating occurs from without inward—the maximum heating occurring at the point of greatest concentration of the lines of current flow; (2) deep heating during diathermy is greater than that which results from the application of local heat to the skin; (3) the lung can be heated by diathermy in spite of simultaneous cooling of the chest.

In considering heat distribution in the various parts of the body, the question of heat loss by conduction, radiation and convection must always be taken into account. In highly vascular organs, such as the lungs, the blood stream always carries away a considerable amount of heat. This occurs especially when the general direction of the blood stream is across the path of the current, such as in transverse application of diathermy to the organs of the chest or abdomen. When the lines of the current flow are the same as the general direction of the blood stream, such as in the case when the current is directed along an extremity, the distribution of the heat effect is more even and a smaller proportion of the heat is carried away by the blood. For this reason, conditions for the control and uniformity of heat distribution along a limb are more satisfactory than in internal organs.

These general principles of heat production and distribution prevail with all methods of diathermy, whereas the passage of current and the distribution of heating vary somewhat with the different techniques.

Heating by Direct Contact.—When metal electrodes connected to the terminals of a long-wave diathermy apparatus are placed in direct contact on opposite surfaces of the body or on the same plane, current conduction and distribution in the heterogenous tissues of the body will vary according to the resistance of the tissues in the path of the current. Under average treatment conditions the current has to pass through a cross-section of the body consisting of tissues of varying electrical resistance. Table 24 shows the specific resistance of the tissues to a high-frequency current of about one million cycles.

TABLE 24.—HIGH-FREQUENCY RESISTANCE OF HUMAN TISSUES (HEMINGWAY AND McCLENDON[11])

Tissue	Ohms	Tissue	Ohms
Skin	289	Kidney	126
Fat	2180	Liver	298
Bone	1800	Heart	132
Muscle (voluntary)	110	Spleen	256
(Tissues from surgical operations)		(Tissues from fresh postmortems)	

Generally speaking, the current will follow the soft tissues and heat them up chiefly; highly resistant parts such as bones and joints will heat up chiefly when they are in the direct and shortest path of the current and even then it is likely that most of the heating effect arises by conduction from the surrounding soft parts and from the superheated blood stream.

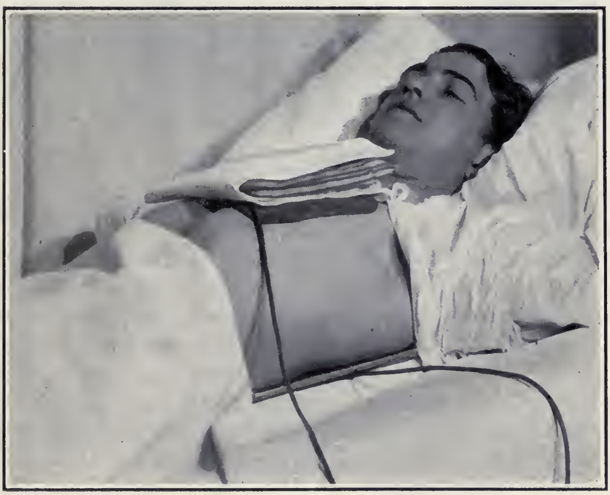

FIG. 150.—Electrodes in position for long-wave diathermy to chest in bed patient. Posterior electrode is slipped in position by depressing mattress; anterior electrode is held in place by light sandbag.

Fatty tissue is the most resistant and this explains why, even under the most careful technique with long-wave diathermy, there may occur at times a coagulation of fat in the subcutaneous tissues when it becomes overheated in the direct path of the current.

Temperature distribution with different types of long-wave diathermy electrodes was investigated by Hemingway and Collins who found that a metallic electrode caused greater cutaneous than muscular heating, while with a saline pad electrode a higher increase of temperature occurs in the muscles than in the superficial layers of tissues.

Heating in the Electric Field.—Currents of a frequency of ten million or more oscillations per second, as employed in short-wave diathermy, can pass more readily through substances which are non-conductive, than a current of lower frequency. These higher-frequency currents can therefore, be conveyed to the body through a layer of air, insulating pad, or an insulated cable. This allows a more flexible and often more convenient and safer technique. There is no need to insure good contact as with metal contact plates, uneven surfaces can be treated, and the problems of edge effect (Chapter V) are greatly reduced.

FIG. 151.—Electric field heating by air-spaced plates held on adjustable arms. (Courtesy of the Lepel High Frequency Corporation.)

It is the physical characteristic of electric oscillations of very high frequency, as stated in Chapter V, that in a condenser arrangement with conductive tissue placed between two electrodes (Fig. 55) part of the electric charge will pass as a conduction current, and part of it as a so-called "current of capacity." It has been found experimentally, that the higher the frequency of the current applied, the greater is the "capacitative" component and the less is the conductive current component. It is therefore claimed that because of the dielectric property of some the ordinarily poor conductive tissues, a very high frequency current may cause effective heating in regions which would otherwise be more or less inaccessible to a purely conductive current. It is claimed that inner organs, spinal cord, brain, which are closed off with poor conductors (fat, bones, etc.) may be heated without overheating the tissues around them.[23] Because of the two different forms of heating it is also contended that the heating effect on the tissues is more uniform.

Heating in the Electromagnetic Field.—A flexible heat insulated cable in the form of a coil or loop is wound around an extremity or is placed in the form of a pancake over part of the body. A high-frequency current traversing such a coil creates a magnetic field and in conductive substances placed inside this field induced currents known as *eddy currents* will arise which flow in a direction opposite to that of the changing current in the coil. If of sufficient strength, the eddy current generates heat in the conductive substance such as the soft tissues of the human body.

Fig. 152.—Electromagnetic field heating. Thermocouple inserted to a depth of 2 inches from the surface of the thigh registers up to 106° F. after a twenty minute application through a cable wrapped around the thigh. (Courtesy of the Burdick Corporation.)

The eddy currents induced in the more conductive materials will be more intense and, therefore, the generation of heat per unit of time will be greater in these than in the less conductive materials. Obviously if a body composed of materials of different electrical conductivities, such as the tissues of the human body, is placed within the field, the intensity of the eddy currents, and consequently the rate of heat generation, will be greatest in those materials of the greatest conductivity. The relative conductivity of the various tissues of the body is about equal to their fluid content, this being about as follows:

Table 25.—Relative Fluid Content of Body Tissues

	Per cent
Muscle	72–75
Brain	68
Fat	15
Skin and bone	5–16

Heating in an electromagnetic field is especially effective in the vascular type of tissue. It is generally designated in the United States as "inductothermy."

The factors relating to coil field heating, according to Pätzold[23] are: (1) the magnitude of the coil inductance (length and shape of the coil); (2) the coil capacity (depending upon the distance between coil windings, on the magnitude of the dielectric constants of the insulating material and on the distance from the coil to the surface of the body) and (3) the length of the wave used. If the frequency of the electrical energy is small compared with the natural frequency of the coil, then the coil functions inductively, by eddy current heating; if the fixed frequencies are large

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compared with frequency of the coil then the coil functions capacitatively by condenser field heating. Efficient heating by a coil field requires proper design of the apparatus. Generally speaking with wave lengths under 10 meters coil field heating is not satisfactory. Holmquest and Osborne[13] have shown experimentally that wave lengths of 25 to 20 meters cause the best ratio of heat generation in physiological saline solution, such as is present in the human tissues.

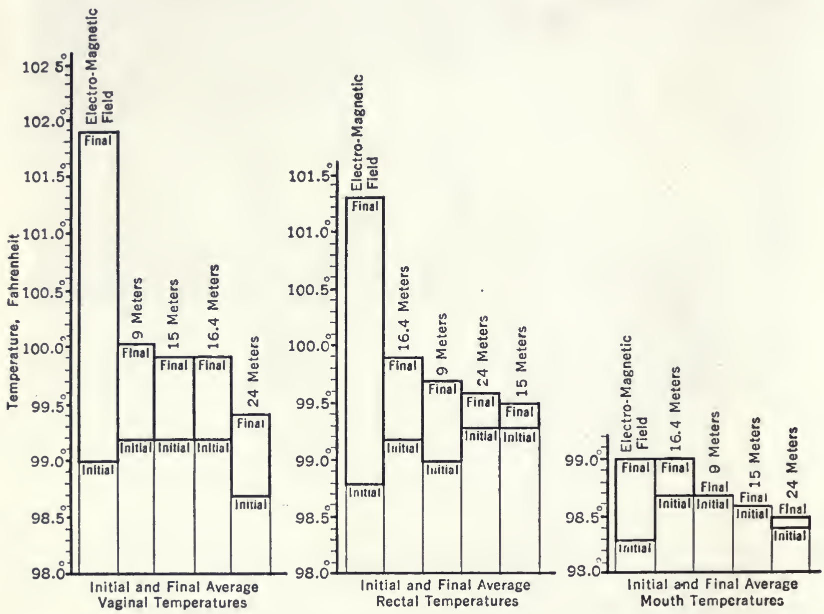

FIG. 153.—Graph showing comparative vaginal, rectal and mouth temperatures produced by electromagnetic field and short-wave diathermy of various wave lengths. (Coulter and Osborne, Arch. Phys. Ther., *X*-ray and Rad.)

Heating in Relation to Wave Length.—In recent years some of the confusing claims as to differences in heating in relation to certain wave lengths became gradually clarified.

Claims for *selective heating* effect by certain wave lengths was based on the early investigations of McLennan and Burton[17] according to which in high-frequency field heating of electrolytes and colloids there is maximum heating effect for a given wave length which is in definite relation to the specific conductivity and dielectric constant. It was correctly pointed out by Mortimer[22] that in the living body the blood flow and the rapid interchange of heat in the living tissues may render the differences in temperature negligible for all practical purposes. The variety of factors influencing tissue heating make it likewise evident that there is no optimal wave length for heating definite tissues in the body.

Coulter and Osborne[4] on the basis of 279 *in vivo* experiments have concluded that wave length in itself is not a marked factor in tissue heating but that differences in apparatus, energy delivered to the patient and technique have important rôles. Their tabulated results are shown in Figure 154. They also investigated the thermal effects on bone and muscle with wave lengths of 6, 12 and 24 meters, and have found that, regardless of wave lengths, muscle temperature was always higher than that of the bone marrow. This in accordance with the generally accepted fact that with any technique of diathermy the thermal gradient is always from the periphery to the interior.

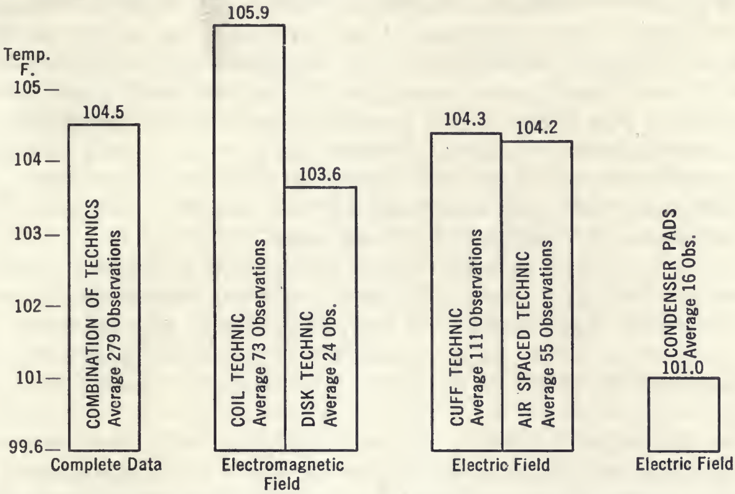

FIG. 154.—Relation of heating to technique regardless of wave length used. (Coulter and Osborne.)

The relative effects of long-wave *versus* short-wave heating have been studied, especially regarding the claim that short waves offer better penetration and consequently deeper heating of the tissues than long waves. Investigating deep heating in the female pelvis with both methods, the same increases of temperature could be produced by both methods with proper technique, using large enough electrodes for long-wave diathermy.

A comparison of deep tissue heating by metal contact electrodes from a 12 meter apparatus and by air spaced discs from a tube apparatus was reported by the author,[14] based on measurements made by William Bierman. These tests proved that cutaneous, subcutaneous, and deep muscle temperatures were substantially the same in both methods of application.

Summing up the present views as to the thermal effects of various methods and techniques of diathermy, it appears to be a consensus of opinion that in actual practice the uniform biological factors: the flow of blood and heat conduction to adjacent colder parts will level off differences very considerably. As a matter of fact clinical results with the different methods are fairly uniform as long as the current is applied within the limit of physiological toleration.

PHYSIOLOGICAL EFFECTS OF DIATHERMY

The physiological and clinical effects of diathermy are due to the raising of the temperature of the parts under the influence of the heating current.

The heat regulating mechanism of the body endeavors to maintain a constant temperature. When heat is applied to a part from any external source, the vasomotor mechanism responds with an effort to dissipate the excess heat. There follows an active vasodilatation of the capillaries and subsequent increase of arterial and venous circulation. There appears to be an inherent tone in the capillaries which causes vasoconstriction. Lewis has shown that irritation of the tissues by the application of heat produces a release of vasodilator substance—histamine—which in turn results in the dilatation of the capillaries. Upon the absorption of the vasodilator substance a greater proportion of the capillaries dilates instead of the few which carry blood under normal conditions; as a result a greater blood supply to the part occurs. This local hyperemia in turn brings about an increase of the rate of removal of local tissue products and stimulation of the local resistive forces. An increase of the histamine content of the blood following diathermy was shown by Hildebrandt.[12] According to the temperature law of Van't Hoff, for every rise of 10° C. the rate of oxidation is increased 2.5 times. Cellular oxidations are easily influenced by changes of temperature of only tenths of degrees, and in the physiological processes of inner organs slight changes in temperature may give results entirely out of proportion to the change; therefore, it does not appear to be necessary that for clinical effects the local temperature be raised to the extent of 4° to 5° F.

When heating is applied in sufficient intensity to a large part of the body surface, general physiological effects arise. A comprehensive summary by Bazett of the combined local and general effects of heating is shown in Table 26.

Table 26.—Effects of Heating (Modified from Bazett)

	Local	General
On circulation:		
Superficial arterioles	Dilated	Dilated
Superficial capillaries	Dilated	Dilated
Superficial veins	Dilated	Dilated
Circulation rate	Increased	Increased
Pulse-rate	Unchanged	Increased
Blood-pressure arterial	Unchanged	Decreased
Blood-pressure capillary	Increased	Decreased or increased
Blood-pressure venous	Increased	Decreased or unchanged
On the blood:		
Alkalinity	Decreased	Increased
Alkaline reserve	Unchanged	Decreased
CO_2 tension	Increased	Decreased
O_2 tension	Increased	Decreased
O_2 content (arterial)	Unchanged	Unchanged or decreased
O_2 content (venous)	Decreased	Usually increased
Phagocytosis	Increased	Increased or unchanged
On the lymph:		
Formation	Increased	Decreased
Alkalinity	Decreased	Increased
On tissues:		
Metabolism	Increased	Unchanged or increased
CO_2 and O_2 tension	Increased	?
On respiration:		
Rate	Unchanged	Increased
Depth	Unchanged	Increased
Volume per minute	Unchanged	Increased
On urine and sweat:		
Volume	Unchanged	Increased
Alkalinity	Unchanged	Increased
$NaHCO_3$ in urine	Unchanged	Increased
Alkalinity of sweat	Unchanged	Increased
Infections:		
Local immunity	Increased (if heat continued)	Increased (if heat is continued

While diathermy undoubtedly produces many of its effects by raising the temperature of deeper tissues, one must not lose sight of the fact that local thermal stimulation of any skin area exerts reflex reactions on deeper structures (Fig. 1). According to physiologists localized hyperemia of the skin is accompanied by localized hyperemia in the corresponding inner organ.

The generally recognized local and general physiological effects of diathermy can be grouped as follows:

1. **Effects on Circulation.**—(*a*) *Local Effects.*—The local application of diathermy results in an active arterial hyperemia which appears to be more penetrating than the hyperemia following external forms of heat applications. In a loop of intestine exposed to the electromagnetic field, a tripling of the blood flow was found by Schmidt, Beazell and Ivy,[28] after the temperature had been raised to 102° F. There is also an increased flow of lymph and as a result of both hyperemia and hyperlymphia there is an increase in the volume of the part thus affected. In glandular organs there is a marked increase of secretion.

(*b*) *General Effects.*—Diathermy applied by a method of general administration results in a dilatation of peripheral blood-vessels, which appears very rapidly; this is accompanied by a rise in body temperature, which in turn results in an increase of the pulse-rate and respirations and an increase of the general body metabolism. Regarding blood-pressure there are contradictory reports in the literature, some authors reporting very marked decrease, which lasts for some time, others found an increase.

Early basal metabolic studies conducted at the Massachusetts Homeopathic Hospital (Granger[8]) showed that under autocondensation (general diathermy), low basal metabolic rates became progressively higher and that in the great majority of cases they tended to remain at an appreciably higher rate after cessation of treatment. Urinary solids hitherto deficient doubled and even trebled in quantity. This corroborated d'Arsonval's pioneer findings on the effects of general high-frequency treatment on general body metabolism, as well as those of Steel,[29] who reported an increased quantity of urine, increase of urea and increase of elimination of nitrogen products after high-frequency treatment. Modern laboratory work with hyperthermy has shown that each degree of rise in body temperature increases the basal metabolic rate about 7 per cent.

2. **Effects on the Nervous System.**—Diathermy exerts a marked sedative effect on irritative conditions of sensory nerves (pain) and motor nerves (spasms and cramps). There is no generally accepted explanation for the pain relieving effect. It may be that heat in some way lessens nerve sensibility, perhaps as a result of inhibition through the temperature nerves of the skin. Short-wave diathermy definitely reduces nerve conductivity in a physiological frog nerve-muscle preparation (Mogendovich[21]). Other investigators called attention to the fact that thermal measures exert reflex action in internal organs by stimulation of the vegetative nervous system through the nerve endings in the skin.

The sedative action on hypertonic conditions of motor nerves is generally explained by the mild heating effects. The relief of muscle cramps by heat is well known and the effect of diathermic heat on hypertonic conditions of the unstriped muscles of the stomach and intestines is the more efficient sequel to the old-fashioned use of a hot brick to relieve colic. It is interesting to note that in experimental studies in normal animals there was no other effect than a slight increase in the rate of contraction per minute. (McLoughlin[17] *et al.*)

3. **Effect on Bacteria.**—It is a well known fact that heat sensitive organisms can be attenuated or killed by heat. Favorable effects of long-wave diathermy on gonococcal infections were reported by the late Cumberbatch[5] and others, but not until the work with fever therapy and the establishment of the variable thermal death time of gonococci was the reason for the somewhat divergent result clarified. (See Chapter XII.) At the same time it has been acknowledged that the disappearance of gonococci and the relief of symptoms may not be due wholly to the direct heat action on the gonococcus, but rather to the secondary effect in the ability of the tissues to exterminate the invading organism by increased phagocytosis and other results of the increased local immunity.

Specific Effects Claimed for Short-wave Diathermy.—The possibility of other effects than heating by high-frequency currents has been a subject for speculation ever since d'Arsonval claimed specific high-frequency effects apart from those of heat. In Chapter V specific electric effects of alternating currents, especially of an ultra high-frequency field were discussed. Liebesny,[16] and Dognon[6] hold that certain phenomena in the short-wave field like stimulation or inhibition of cellular activity cannot be explained on the basis of the thermal factor only. Non-thermic changes induced in colloidal particles by an electric field are proven, according to Krasny-Ergen[15] by the fact that their manifestations are depending on the direction of the electric field. (Fig. 56.) Liebesny[16] was actually able to photograph these effects in films. The existence of a specific non-thermal effect of alternating currents which takes a particular course in the short-wave field must therefore be considered possible, although so far it has no practical clinical meaning.

Among the specific biological effects claimed for short-wave diathermy were effects on capillaries (Pflomm), on tumors (Schereschewsky,[26] Reiter[24]), and specific bactericidal action (Haase and Schliephake[10]).

Some observers described "athermic" effects which come about by employing only a low output of a short-wave apparatus, and claimed specific influence on the autonomic and sensory nervous system. All these claims were disproved one by one in the literature of the past decade, and summing up all the available evidence at present it would appear that besides the possibility of specific electric changes, thermal effects are the only proven biophysical effects of short-wave diathermy. The diversity of opinions and of some of the conflict in the experimental and clinical findings can be attributed to two factors. One is the undoubted lack of training in biophysical research in some of the investigators. The other factor is the lack of a generally accepted method of dosimetry. In order to be able to compare results in intricate biophysical research one must recognize the elementary biophysical law of a minimum energy threshold as well as an optimum dosage for certain effects, and one must also be able to employ comparable amounts of energies.

It is the consensus of present day medical opinion that short-wave diathermy is a specific form of heat therapy which differs from long-wave diathermy chiefly in the mode and extent of passage through tissues.

CLINICAL USES OF DIATHERMY

The therapeutic indications of diathermy are based upon its enumerated physical and physiological effects. The heat of diathermy is generated in the tissues by the direct action of electrical energy, and in its gradual introduction does not appear to bring about such a marked reflex action of the heat-regulating mechanism as "external" forms of heating. The placing of electrodes directly over the heated parts also prevents any considerable cooling by evaporation.

Deep hyperemia causes an increased arterial flow with more oxygen and improved nutrition, while the greater venous flow carries away in larger degree the products of local metabolism. These effects promote disintegration of inflammatory exudates and assist in their resorption, as shown clinically by the decrease of swelling, relief of pain and restoration of function. Hence the therapeutic effectiveness of diathermy in subacute and chronic inflammatory and congestive conditions and circulatory disorders. The pain and spasm relieving effect of diathermy makes its use indicated in irritations of sensory and motor nerves, while the effect on thermolabile organisms such as the gonococcus makes it of specific value in the treatment of gonococcal infections.

Diathermy is often indicated alone; in some conditions it will work to best advantage if properly combined with other physical measures, notably with those producing mechanical effects. A brief enumeration of the principal conditions in which the use of both long- and short-wave diathermy has become a standard aid in treatment is as follows:

In traumatic and inflammatory conditions of bursæ, bones and joints after the acute stage, also in delayed union of bones when there is a fair degree of fixation, and in painful and exuberant callus formation and fibrous ankylosis following joint injuries.

In chronic inflammations of abdominal organs, such as the gall-bladder and ducts, where surgery is contraindicated. In peritoneal adhesions following gastric or intestinal conditions, and in postoperative adhesions diathermy is advantageously combined with muscle exercising currents. Spastic conditions of the stomach, gall-bladder, intestines and pelvis of the kidney, as well as gastric neuroses, are frequently relieved by diathermy. Subacute and chronic inflammations of the female organs, such as metritis, parametritis, diseased adnexa, respond well because of the efficient localization of deep heating; the same relates to gonorrheal infections and to prostatitis, epididymitis and seminal vesiculitis in the male.

In congestive chest conditions, such as acute, subacute and chronic forms of bronchitis, as well as in pleurisy, diathermy helps to relieve pain, loosens cough and speeds recovery, while in essential forms of bronchial asthma relaxation of muscular spasm follows its application. In the pneumonias diathermy offers a valuable adjunct to standard forms of therapy.

In the treatment of neuritis, and in certain varieties of neuralgia or myalgia, diathermy helps to relieve pain and also promotes resorption of inflammatory changes. In angina pectoris, in essential forms of hypertension and in selected cases of peripheral vascular disease, diathermy may serve as a useful adjunct to other medical treatment.

In organic nervous disorders, such as general paralysis, and locomotor ataxia and other syphilitic affections of the central nervous system, artificial fever therapy by diathermy is being successfully employed.

Details of indications and technique of the application of diathermy in most of the enumerated conditions will be found in the special chapters of Part V.

Claims have been made for specific action of short-wave diathermy in acute skin infections such as furuncles and carbuncles and lung abscesses, but seasoned medical opinion attributes the undoubted clinical relief rather to the fact that only mild heating was applied, which is always beneficial in such cases.

Short-wave "provocation" as a diagnostic aid in suspected foci of infection has been proposed[9] because of a fairly consistent increase in the blood sedimentation rate when short-wave diathermy was applied to the site of an active dental infection. Similar changes in the sedimentation rate following abdominal diathermy in pelvic infections were also reported.

The indications of the two special forms of long-wave diathermy, the Oudin current and autocondensation will be presented later on.

Short-wave vs. Long-wave Diathermy.—The advantages of the simplified technique and increased adaptability of short-wave diathermy and the enthusiastic reports on its clinical results in a very large number of conditions seemed to have doomed long-wave diathermy in general and the contact plate technique in particular to oblivion. American manufacturers have actually discontinued the making of long-wave apparatus for medical purposes, although for electrosurgery spark-gap apparatus is still being made and it is essential for administration of the Oudin current. However, it is the opinion of most seasoned observers that long-wave diathermy still holds its own very definitely.

Because of convenience of application short-wave technique may be preferable for certain locations or conditions. For instance, inductance coil heating is very convenient in peripheral vascular conditions for gentle heating effect on account of easy controllability and the avoidance of skin contact; also for treating two knees simultaneously. In conditions of the head sinuses and for facial involvements, the spaced air plate or treatment drum method of short-wave diathermy is quite convenient and fairly safe.

In gynecologic conditions clinicians generally state as an advantage of short waves their applicability and efficiency in acute cases, whereas long-wave diathermy is only indicated in chronic cases (Chapter XXX). The contention that short-wave diathermy is preferable in acute cases and long-wave diathermy in chronic cases can be explained by the fact that, with the original air-spaced technique, as a rule mild heating is applied which is well tolerated and beneficial in acute cases. Long-wave diathermy with the contact-plate method results usually in more intense heating, better suited to chronic cases.

In the light of present knowledge, acute inflammatory conditions are the only ones in which short-wave diathermy may be considered to be definitely preferable over long-wave diathermy because of different clinical effects. In all other conditions either method can be employed. Long-wave diathermy or the contact plate method of short-wave diathermy seem preferable in all techniques where the spreading of lines of force and unnecessary heating of adjacent structures is to be avoided. Short-wave diathermy as usually applied with large size electrodes and an inductance coil results in a great deal of wasted energy and makes heat sensitive patients feel quite uncomfortable. In all such cases and also in such locations as the neck and head, where unnecessary heating of non-affected parts is to be avoided, clinical experience of the author and a number of others has shown that the contact plate technique by either long- or short-wave diathermy is more efficient. In treating superficially located muscles and bursæ, many of the joints and the cervical spine it allows better localized heating. In the author's opinion, it is still the method of choice for orificial treatment of the pelvic contents. Long-wave diathermy as well as the contact plate short-wave technique always allows the use of a meter and thus a better control of the dosage instead of the subjective sensation of the patient.

CONTRAINDICATIONS AND DANGERS OF DIATHERMY

Diathermy is *relatively* contraindicated in disease processes in which the usual safer methods of superficial heat give satisfactory results. Ordinary contusions, simple myositis, will readily respond to luminous heat, the same form of heat causing acceptable results in bronchitis of children and in non-purulent forms of sinusitis or otitis media. So, too, complicated methods recommended by some for applying diathermy to fingers and toes seem superfluous in view of the fact that such areas can be more effectively and more safely heated by radiation, hot water or paraffin baths. Superficial neuralgias and neuritis can be frequently relieved by radiant heat followed by a mild application of the Oudin current or in resistant cases by galvanism.

Diathermy should not be used as a panacea for all sorts of undiagnosed painful conditions. A complete diagnosis, a definite conception of the underlying pathology to be influenced and consideration of the individual equation in each patient are essentials for its successful application.

Diathermy is *absolutely* contraindicated in three conditions: (1) In acute inflammatory processes accompanied by fever and suppuration. The pain and swelling of acutely inflamed joints in infectious arthritis are usually aggravated by diathermy, and it is almost a diagnostic evidence that the process has entered the subacute stage when diathermy can be well tolerated. In acute, non-draining suppuration, such as otitis media, appendicular abscess, acute pelvic infections, unwisely applied diathermy may lead to real danger by spreading the process. (2) In tendency to hemorrhage. Diathermy must not be employed in recent hemoptysis, in bleeding gastric ulcer, in large varicose veins, and in pregnancy. It is inadvisable to apply diathermy to pelvic organs during the menstrual period. (3) In malignant tumors or in case of the suspicion of such.

Coulter[3] considers peripheral nerve injuries absolute contraindications, for the reason that the disturbed or absent skin sensitivity greatly increases the risk of burns. The author is of the opinion that in experienced hands in many instances the benefit of diathermy may outweigh its danger, especially as burns are just as liable to occur under any other form of heating.

In acute inflammatory conditions accompanied by suppuration and fever, long-wave diathermy has always been considered contraindicated, while competent observers have reported unquestionably good results by the application of mild doses of short-wave diathermy. Some reason for its applicability is the fact that air-spaced plates can be employed where contact electrodes would cause painful pressure and possibly excess heating. Great care must always be exercised, a minimal dosage applied and the principle of the necessity for surgical drainage in purulent infections always be kept in mind.

The danger of burns is present in any form of thermal therapy and is especially prevalent with metal contact plate conveying large amounts of electrical energy, as shown by the not infrequent burns with long-wave diathermy in inexperienced hands. With short-wave diathermy this danger is relatively less but burns by this method will also happen, for a variety of reasons. Proper technique and the observation of all precautions enumerated in Chapter V are essential at all times for their prevention.

GENERAL TECHNIQUE OF DIATHERMY

General Considerations.—The object of both long- and short-wave diathermy is to produce penetrating heating of the entire body, or of a part of it. Effective heating will depend on the correct selection of treatment technique, as well as on the proper dosage and duration of the treatment.

The selection of the method of treatment, long wave or short wave, and particular technique, electric or electromagnetic field or direct conduction heating, will depend on the available apparatus and on the condition to be treated in the individual patient. Generally speaking, all forms of diathermy when applied intelligently will result in satisfactory deep tissue heating. Certain techniques are, however, preferable because of convenience or safety for certain locations and certain pathological conditions, as has been already pointed out and will be further stressed in this chapter as well as in Part V.

Regulation of Dosage.—Medical diathermy must be a pleasant procedure at all times, and must never cause pain during treatment, or damage to the tissues. As a general rule, the strength of current should be no more, at any time, than that which feels comfortable to the individual patient. We have not enough experimental data to tell us at what degree of heat best therapeutic results are achieved, neither have we any practicable device for the exact measurement of the heat attained in the interior of the body, except in electropyrexia where the temperature of the body as a whole can be measured by thermometry. In long-wave diathermy the reading of the milliampere meter is a definite help in regulating the amount of current passing on to the patient. The meter in short-wave apparatus only serves as an indicator that electrical energy is passing; but it does not register the amount of energy passing through the patient. "Dosimeters" have been constructed for short-wave apparatus measuring the power absorption by the patient (Mittelmann and Kobak[19]), but have not stood the test of general clinical use.

The *heat sensation* of the patient is the supreme guide of dosage in all diathermy treatments. Hence the physician must be certain at all times that the patient perceives heat normally and in doubtful cases, testing by test tubes filled with hot and cold water should be done. Long-wave diathermy is more apt to cause unpleasant skin sensations when applied even in small excess or with incorrect technique; particularly with the spark gap opened too wide there occurs an unpleasant "faradic" sensation even with a minimal amount of current. A definite excess amount of current will manifest itself by an unpleasant burning sensation in the skin or a feeling of pressure in the subcutaneous tissues. Patients complain of the latter, especially when in longitudinal (cuff) application too much current is crowded into a narrow area, such as the wrist or ankle.

Short-wave diathermy produces more of a smooth, "velvety" sensation of heat, which many patients prefer. Four grades of heat sensation in short-wave treatments have been established by several clinicians: (1) threshold value (glow-like sensation); (2) distinct feeling of agreeable warmth; (3) intensive heat; (4) unbearable heat. An effort has been made to correlate these heat sensations to the power absorption (Mittelmann and Kobak). For very mild dosage, as in acute inflammatory conditions one should stay within the glow-like sensation, while in chronic cases the sensation should be just this side of intensive heat.

A rapid rise of heating by fairly strong amounts of energy is not desirable in deep heating with either long-wave or short-wave diathermy. In treating internal organs, especially the thoracic, abdominal and pelvic organs, a moderate amount of current and comparatively long treatment produces better effects. This is partly explained by some experiments by Fürstenberg and Schemel[7] conducted on the dog's stomach, using thermocouples for measuring its temperature. By directing a current through the abdomen they found that stronger currents produced a slighter rise of temperature than weaker currents. When the dog was killed the temperature in the stomach rose with the increase of current and dropped with its decrease. The apparent contrast is explained thus: Strong currents caused in the living animal a reflex vasodilatation of the heat-regulating blood-vessels and thus the excess heat was led away. Weaker currents, on the other hand, applied over long periods, cause considerable deep heat effects without stimulating the reflexes. The same findings were obtained recently with currents of low and high wattage in short-wave diathermy (Mittelmann,[20] *et al.*). As long as the absorbed power does not exceed 100 watts, the temperature in the deep tissue raises in a straight line until near termination of the twenty-minute treatment period. If the power absorption exceeds values much over 100 watts, the final temperature is actually much lower. This may be also explained by the rapid dissipation by the increased blood circulation. Weaker currents to the extremities are indicated, as a general rule, in acute painful conditions, such as in acute neuritis, recent cases of traumatism, and also in chronic arthritis with marked trophic changes. In treatment of acute inflammatory conditions by short-wave diathermy best results have been achieved with ten minute applications of low intensity.

Mucous membranes can stand larger amounts of current than the skin. This is partly explained by their much better vascularization, which enables excess heat to be carried away much faster than in the skin, furthermore the lessened electrical resistance of the membranes decreases the amount of heat produced.

Duration and Frequency of Treatment.—It is evident that it takes a certain amount of time for the temperature of the part treated to reach the desired height and then, through automatic heat regulation (the blood stream and conduction by the surrounding tissues), a condition of equilibrium will ensue so that a fairly constant temperature is maintained. It is also evident that superficial parts can be heated in less time than deep-seated structures, therefore longer treatments are indicated for inner organs.

Clinical experience has established that *twenty minutes* is the minimum time required for an efficient diathermy treatment in extremities or superficial parts of the body. In treatment of internal organs about one-half hour or even longer treatment is advisable. Excessively long treatments may cause too intensive a heat effect and thereby exhaust the patient, especially if he is aged.

Acute and very painful conditions or recent injuries in which the early return of function is essential, as a rule, require daily treatment. With improvement of such conditions this repetition can be reduced. For the average patient suffering from some chronic ailment, treatment on alternate days usually suffices and may be administered even less often, dependent upon the progress noted.

TECHNIQUE OF SHORT-WAVE DIATHERMY

Electrodes.—Each of the three forms of short-wave diathermy application involves the use of different types of electrodes.

Table 27.—Electrodes in Short-wave Diathermy Application

1. Electric or condenser field heating	Flexible condenser pads, air-spaced plates, single and double cuffs
2. Electromagnetic field heating (inductothermy)	Inductance cable wound round part or placed upon body in form of a loop, pancake coil, treatment drum
3. Direct contact heating	Metal contact electrodes for vaginal or rectal application with condenser pads for dispersive electrode, metal contact electrodes all around with apparatus with extra condenser in patient's circuit.

1. **Electric or Condenser Field Heating.**—Electric field heating consists of applying two spaced metal electrodes—condenser pads and cuffs, or air-spaced electrodes—either on opposite surfaces or the same body surface to heat the interposed part. These electrodes have been already briefly described in Chapter IV.

Condenser pads are held in place by elastic bandaging or perforated rubber bands or by some other suitable means, such as sandbags or by the patient resting on them. The advantage of pads is their pliability which enables their bending or shaping to conform with the surface to be treated. The rubber insulation of imperfectly jointed or pressed pads may puncture with subsequent danger of arcing and burns through the exposed part of the metal. For this reason, and for the avoidance of overheating of the skin the pads should never be placed directly over the skin; a dry towel or some other dry insulating material such as perforated felt, of at least $\frac{1}{4}$-inch thickness should be interposed. In applying the pads care must be taken that their cable connection should nowhere directly touch the patient's skin.

Accumulation of moisture due to perspiration under the electrodes leads to a concentration of electrical energy near the skin and the possibility of superficial burns. Hence, it is a general rule to place in addition to suitable spacing, moisture absorbing material between the electrodes and the skin. If turkish towels are used for spacing this is not necessary; in all other cases, linen or paper towels, thin blotting paper or tissue paper should be employed. Felt pads used for spacing should always be free from moisture.

Fig. 155.—Flexible condenser pads applied to shoulder.

Double cuffs consist of a pair of long and narrow condenser pads which are applied along an extremity at suitable distance from each other. They should be so placed that they include only the part to be heated and the skin-electrode distance under both cuffs should be equal. It makes no difference if part of the cuff overlaps.

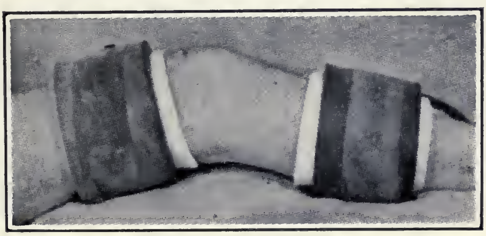

Fig. 156.—Double cuffs applied to knee.

Air-spaced condenser plates consist of circular metal plates or discs covered with insulating material. The plates are mounted on adjustable arms in the form of treatment arms and are self retaining in any desired position and distance. (Fig. 151.) This is especially convenient over the knees, shoulders and cavities of the head. Spaced glass electrodes consist of a hollow cylindrical glass "shoe" containing a metal plate which can be moved back and forth parallel to the bottom of the glass cylinder and held at the desired distance, usually between ½ and 3 inches from the body. The advantage of glass as an electrode cover is that it does not become heated as rubber does and does not deteriorate through use. These glass condenser electrodes have found little employment in the United States.

The correct spacing of these various forms of electrodes is quite a problem. Generally speaking the thicker the part of the body to be treated the greater should be the skin-electrode distance and the greater should be the size of the electrodes. It is important to follow the instructions given by the manufacturers for the correct spacing in relation to the power output of their apparatus. Figure 157 diagrammatically shows the influence of spacing on the underlying tissues. Under certain conditions it may be desirable to produce more surface heating on one side and more depth effect on the other; this can be done by using less spacing on one side and more on the other.

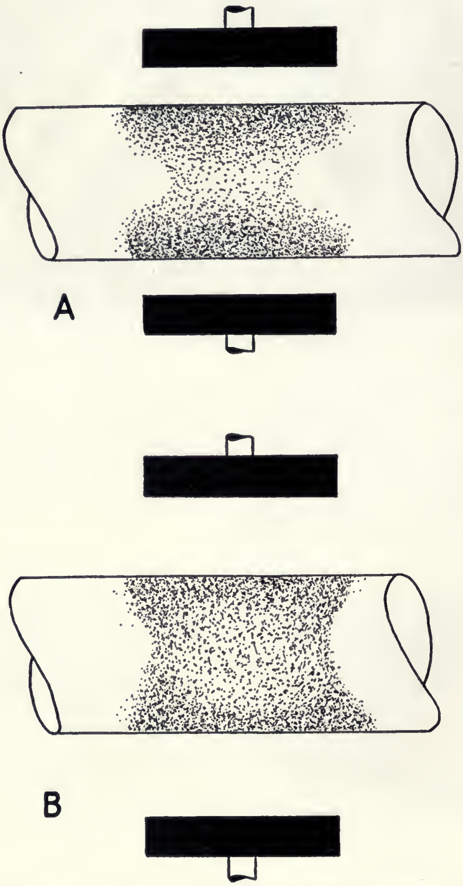

Fig. 157.—Schematic diagram of influence of spacing on extent of depth effect. *A*, close spacing, more superficial heating; *B*, wider spacing, more depth heating.

2. **Electromagnetic or Coil Field Heating.**—Coil field heating or inductothermy serves for heating an entire extremity or part of it; it also serves for fever treatment. To treat an entire extremity or a joint two to four thicknesses of turkish toweling should be placed between the cable and the skin. There should be two to four turns of the cable wound round the part to be treated depending on its size; these turns should be spaced 1 inch or more apart; convenient wooden "spacers" serve for this purpose. In all inductance cable treatments the ends of the cable leading to the appa-

ratus should be of equal length and should be separated at least the distance of the outlets on the apparatus. (Fig. 158.)

Instead of winding an inductance cable around an extremity, it can be applied in the form of a pancake or held in a so-called treatment drum in a similar circular form. In this form, it can be applied on any part of the body, held at a proper distance by interposition of spacing by felt or by air. The turns of the pancake coil should be about 1 inch apart from each other. The advantage of this type of electrode is its convenience of application to anatomic location, its disadvantage is the unnecessarily extensive heating of adjacent parts when treating such small locations, as the ear, eye or sinuses. (Fig. 48.)

Fig. 158.—Heating of elbow by electromagnetic induction (inductothermy) in coil field. (Courtesy of the Burdick Corporation.)

3. **Direct Contact Heating.**—Direct contact heating by metal electrodes applied to the skin without any spacing involves a technique similar to long-wave diathermy. It is only possible with apparatus so constructed that an extra condenser in the patient's circuit makes up for the lack of spacing. (Fig. 159.) In applying this method, the principle of spacing is given up, but the advantage gained is the possibility of using a milliammeter for correct reading in the patient's circuit. Experimental evidence has shown that the heat effect in the depth is the same as with air-spaced electrodes; in addition there is less electrical energy needed because there is no wasted radiation into space.

For cavity work in the vagina and rectum, contact heating avoids cumbersome glass sheathed electrodes. If in electric field heating one electrode is applied by direct contact to a cavity, such as the rectum or vagina, the output of the apparatus must be balanced by adequate spacing of the other electrode—by placing it sometimes far below the wooden treatment table. With apparatus equipped with the extra condenser the dispersive electrode can be applied in direct skin contact over the abdomen or back.

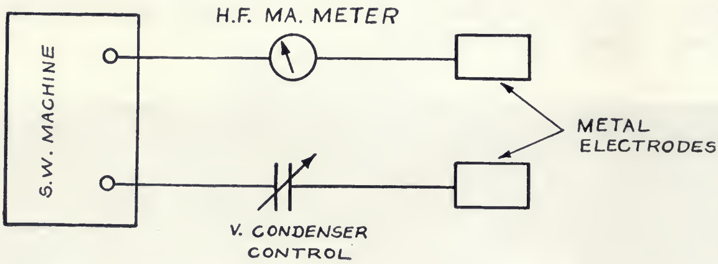

Fig. 159.—Schematic diagram showing one method of using contact plate technique with a short-wave generator. The controls of the generator are used in conjunction with the auxiliary variable condenser control shown. So-called "blocking" condensers are essential in this adaptation and are found in most short-wave generators. If omitted, they must be provided in the addition to the above circuit. (Courtesy of A. P. Mooradian.)

The *choice of* one of the three *methods* described is by no means clear cut, because it involves several considerations. Experimental studies show that coil field heating is the most efficient for soft parts. Clinically,

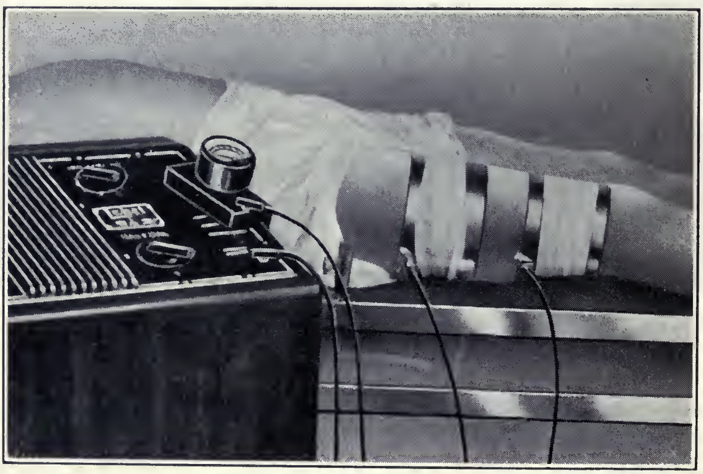

Fig. 160.—Milliammeter inserted for direct reading in short-wave treatment by contact plate technique in apparatus equipped with blocking condensers. (Courtesy of Lepel High Frequency Laboratories.)

it seems possible to get equally good results with any of the methods described by suitably varying the size of electrodes, their spacing and the length and strength of treatment.

For regulation of dosage in short-wave diathermy the heat sensation of the patient is at present our only guide. For this reason it is imperative to ascertain beforehand that the sensory perception of the patient is normal or near normal.

In proceeding with the treatment therefore, the initial strength of the current must be adjusted in accordance with previous experience and be guided by the patient's sensation, as stated in the previous section.

TECHNIQUE OF LONG-WAVE DIATHERMY

Long-wave diathermy consists of the application of bare metal electrodes to opposite surfaces of the body. This technique is more exacting than that of short-wave diathermy and therefore gives a better foundation for the general use of diathermy.

Electrodes—Their Position and Size.—Metal electrodes cut of soft sheet metal, described in Chapter IV serve for the entrance of the high-frequency current through the skin; suitable shaped metal electrodes serve also for vaginal and rectal treatment. These electrodes must be held and applied in perfect contact throughout the treatment. This is usually done by an elastic bandage, but it must not be applied too tightly because the parts expand as they warm up. On a flat surface the electrodes can be held by sandbags and there are also available ready-made electrodes in holders. Preliminary warming of the part to be treated, as well as of the electrodes by radiation from a heat lamp is advisable; this will also moisten the skin and make for better contact, and also take away the chill of a cold metal. Sharp edges and wrinkles in electrodes must be smoothed out beforehand. Usually no interposition of soaping or electrode jelly is needed for perfect contact except in patients with abnormally dry or tough skin.

Fig. 161.—Diathermy to elbow. Cuff method.

The relative position of the electrodes may be transverse or longitudinal (Chapter V). The transverse method serves for treating joint and ligamentous-bony structures and internal organs. With electrodes of equal size and fairly parallel there should be an even distribution of current in areas of the same electrical resistance. To concentrate diathermy over a circumscribed area—as in painful tendon insertions, circumscribed periosteal inflammations or in the subdeltoid bursa—a small plate of thin tinfoil is moulded over the spot and a large dispersive electrode placed over the chest on the opposite side. This also avoids heating up large masses of tissue unnecessarily as it is constantly done in short-wave diathermy.

The longitudinal (cuff and semi-cuff) method when two suitably curved plates are placed fully or partly around an extremity, will principally warm the skin, the muscles, the periarticular structures and nerves, which are not too deeply situated. Circular cuffs should be placed around an extremity only if the limb can be fully extended, otherwise the current will concentrate more on the surface where the electrodes are closer to each other. Cuffs must be kept from 12 to 15 inches apart, for if too close the current will have the tendency to pass along the skin only. Exposing of the area between cuff electrodes to a heat lamp during treatment will diminish heat loss by radiation from the skin and increase the deep heat effect.

With electrodes in tilted position toward each other, the current always takes the shortest path between the electrodes and thus there will be more heat where the surfaces converge. If the two electrodes are placed practically on the same plane the heating effect will be limited to the area between the near edges. This "edge" effect must always be anticipated when electrodes are placed in other than exact opposition to each other. Wherever there is increased density of the current in a shorter path or in a path of lower resistance, there is likelihood of a burn, if the limit of physiological toleration is exceeded.

The Reading of the Milliampere Meter.—While the patient's heat sensation is our supreme indicator at all times, the milliammeter is nevertheless an important guide in applying diathermy with contact plates. The meter only indicates the amount of current flowing in the circuit of the patient, and not the absolute amount of heat developed in the tissues. Its reading must always be considered in relation to the size and position of electrodes. The larger the size of the electrode, the more current can be administered.

The relation of milliamperage to the size of the active electrode is known as current density. A fairly generally accepted method of calculation is to figure from 75 to 100 milliamperes per square inch of the active electrode when applied to the normal skin. Table 28 gives an estimate of maximum milliamperage with standard sizes of electrodes in individuals with normal skin sensation, and with electrodes equidistant and opposite each other. With electrodes of unequal size maximum milliamperage has to be estimated according to the size of the smaller active electrode.

Table 28.—Maximum Milliamperage for Diathermy by Direct Contact

Average Estimate 100 Milliamperes per Square Inch

				Electrode surface				Milliamperage
2	×	2	=	4 sq. in.	×	100	=	400 MA
3	×	3	=	9 sq. in.	×	100	=	900 MA
4	×	4	=	16 sq. in.	×	100	=	1200–1400 MA
2	×	4	=	8 sq. in.	×	100	=	800 MA

The increase of milliamperage does not increase the heat effect in the same proportion, but, according to Joule's third law, in relation to its square. A double amount of milliamperage, therefore, results in four times the amount of heat under the electrode. This explains why patients are often so sensitive to a slight increase in milliamperage after the limit of comfortable toleration is reached.

There is very marked sensitiveness of the skin to the application of diathermy on large areas of the abdomen and with electrodes of large size the milliamperage cannot be increased in the same proportion as over other parts.

The calculations of Table 28 cannot be applied when using cuff electrodes or active electrodes of larger surface than 4 by 4 inches. In the cuff method the tendency of the current to take the shortest and least resistant path from electrode to electrode will lead to increased density in the near edges of the cuffs and, therefore, the safe amount of current is determined by comfortable toleration of the individual and by the experience of the operator.

REGIONAL TECHNIQUE OF DIATHERMY

The general principles of application of long- and short-wave diathermy to various regions and organs are in many respects similar. The three forms of technique by short-wave diathermy allow quite a variety of application and flexibility of technique in certain locations.

Fig. 162.—Diathermy to brain.

Brain.—The brain is an excellent conductor of electricity, due to its abundant content of water; however, it is encased in bone which is a poor conductor, as is the fibrous scalp. A metal electrode placed on the skull creates a physical arrangement equivalent to a condenser, and represents one plate of the condenser, the brain the other; between these two lies the poorly-conducting bone-skin-layer representing the dielectric. The transmission of the current from one plate to the other of the condenser is effected by virtue of its capacity; the bony skull-cap itself possesses a small conductive capacity on account of the blood-vessels contained in it. In the experiments of Schliephake[27] a thermocouple inserted in the brain showed an increase of temperature of 0.9° C., a thermocouple within the temporal muscle showed an increase of 3.3° C. and one in the skin of the top of the skull showed a rise of 1.8° C.

Short-wave diathermy may be applied to the brain by condenser pads or spaced plates, held antero-posteriorly or bitemporally with suitable spacing. Treatment must be always applied with the patient in recumbent position, to minimize possible dizziness. The current should be turned on very gradually and should only be strong enough to produce a pleasant feeling of warmth. A strong current may cause dizziness or headache. Treatment should last from fifteen to twenty minutes and the patient must be left in the recumbent position for at least ten to fifteen minutes afterward.

Long-wave diathermy to the brain may be applied by the lateral transverse method; two small electrodes 2 by 2 inches are placed on both temples and held by an elastic bandage; interposition of wet gauze or electrode jelly is advisable to avoid undue pricking at the beginning of the treatment. This method will heat the mid-brain, the temporal lobes, part of the frontal lobes and may reach the hypophysis. (2) In the antero-posterior method (Fig. 162) larger electrodes—about $2\frac{1}{2}$ by 4 inches can be applied. One is placed across the forehead, the other on the back of the head at the hairy border, or even on the hair; in the latter case electrode jelly should be interposed to moisten the hair.

Fig. 163.—Condenser pads for head sinuses. (Courtesy of Burdick Corp.)

Eyes.—Short-wave diathermy can be applied by the pancake coil technique: a pillow is placed over the coil and the patient's face rests on it with the eye in the center. Long-wave diathermy allows a more exacting technique. An active electrode is cut from sheet metal into a shape conforming with the contour of the eye and placed over the lid, a larger dispersive electrode is placed under the nape of the neck. It is better to use wet gauze or electrode jelly under both electrodes to avoid air spaces and undue pricking. Care must be taken in insulating the cord tip well when attaching it to the eye electrode. For treating of both eyes two similar active electrodes can be cut and connected by a split cord. There are also available ready made eye electrodes, consisting of glass cups on a suitably wired handle; the depression of the cup is filled with well moistened cotton and placed over the eye. Only about 200 to 250 milliamperes can be tolerated over one eye and proportionally more over two.

Fig. 164.—Air-spaced treatment for antrums and facial structures. (Courtesy of McIntosh Electrical Corporation.)

Fig. 165.—Throat treatment by inductance coil.

Head Sinuses.—The sinuses of the head may be treated by short-wave diathermy by a pancake coil or a condenser pad (Fig. 163) placed over the face. For individual sinuses a small condenser pad or spaced plate is employed and a larger dispersive pad or plate held opposite the active electrode. For further details, including treatment of ears see chapter on ear conditions.

Long-wave diathermy to the sinuses is risky in the hands of the inexperienced because direct metal contact over a bony surface may lead to a burn.

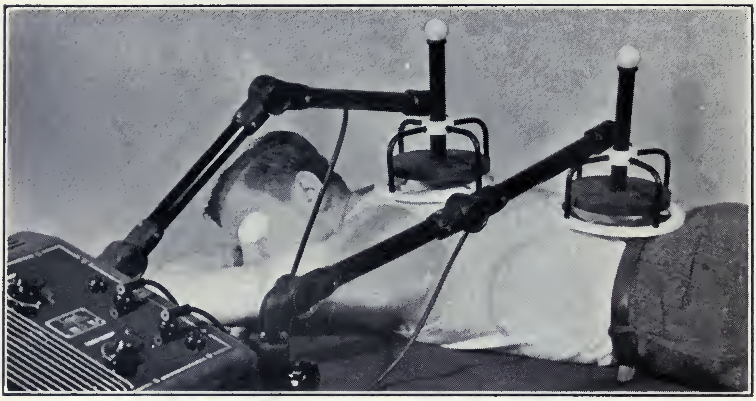

Fig. 166.—Treatment of spine by spaced plates.

Neck.—The cervical spine may be treated with condenser pads either antero-posteriorly (a narrower pad over the cervical spine, a dispersive pad over the upper anterior chest) or laterally (two equal-sized pads on each side of the neck). Spaced plates may also be applied. All structures of the neck may be treated by several turns of an inductance cable, wrapped

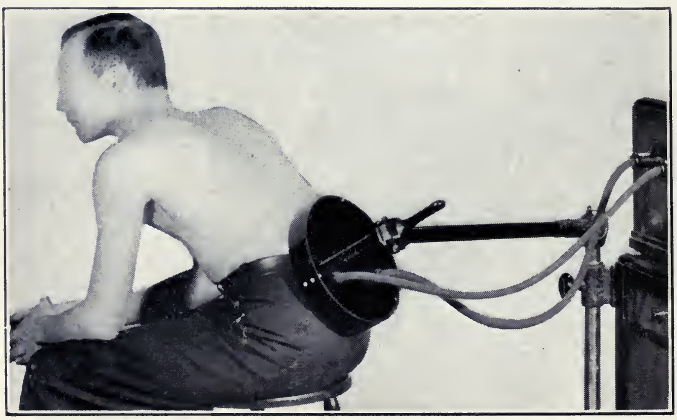

Fig. 167.—Treatment of lower back by disc electrode.

around several thicknesses of turkish toweling. Finally, a few turns of the pancake coil may be placed over the cervical spine with toweling interposed.

For long-wave diathermy, two equal-sized electrodes about 2 inches long are placed on the lateral aspects of the neck and held by bandaging. While a certain tilting of the electrodes toward the spine cannot be avoided, they can be kept far enough apart to allow about 600 to 800 milliamperes of current to pass, and this will cause a heating of the intervening parts.

Dorsal and Lumbar Spine.—The dorsal spine may be treated with the patient lying on his back or abdomen having one narrow condenser pad placed over the dorsal spine and a large dispersive one over the abdomen. The pancake coil may be also applied to the spine with the patient lying face downwards.

The lumbar spine and the sacro-iliac joints may be treated similarly by transverse condenser pads or by the pancake coil. In the sitting patient spaced condenser plates may be employed, a smaller active one over the region to be treated and a larger one held opposite. Suitably interposed toweling or felt pads are always essential.

With long-wave treatment, the patient is placed in either the dorsal or the ventral recumbent position and the electrodes then placed antero-posteriorly. The posterior electrode is the active one and should correspond in size with the area of the spinal column or cord to be treated, the anterior one should be the larger and be placed on the opposite surface of the chest or abdomen. This technique concentrates the path of the current chiefly over the relatively narrow area of the spine.

Coccyx.—Treatment by the contact plate technique is the most suitable and efficient for treatment of the coccyx. The patient is placed in the ventral recumbent position and a cylindrical electrode (round prostatic electrode) is inserted about 1½ inches into the rectum and held in position by sandbags; a piece of tinfoil of suitable shape and size, about 1½ inches square, is placed directly over the coccyx and held by adhesive straps or a small sandbag. The patient may also lie in a dorsal position on the coccygeal electrode placed on a pillow. Current is applied at comfortable toleration, about 250 to 300 milliamperes.

Organs of the Chest and Abdomen.—The possibility of directing diathermy through every cavity and organ of the body makes it a therapeutic measure of unique potency. Diathermy can be applied to the lungs, the heart, the mediastinum, the liver and gall-bladder, stomach and gastro-intestinal tract, to the kidneys and, finally, to the pelvis and to every one of the genito-urinary organs. The general principles of application are as follows:

1. Electrodes must be of sufficiently large size to allow for the inevitable dissipation of the current in the center; this is just the contrary to the former incorrect teaching, which maintained that the diathermic heat could be focused between the electrodes. The heat of diathermy always begins at the surface and travels inward. It is preferable to have electrodes of an equal size, unless one wishes to restrict the heat action to the area of the smaller electrode.

2. Efficient treatment of internal organs demands a treatment time of from half an hour to one hour, because more allowance must be made for warming up the intervening parts. The increase of current strength should always be made gradually so as to avoid unnecessary deep reflexes and increased heat dissipation.

Lungs.—Ambulatory cases of bronchitis, bronchial asthma and pleurisy can be treated with the patient sitting up in an arm-chair. With short-wave diathermy, treatment may be given by condenser pads or contact plates placed antero-posteriorly, by an inductance coil wound round the chest, or by a pancake coil placed over the anterior surface (Fig. 168). With long-wave diathermy, a plate electrode 5 by 6, is placed over the middle of the back, one of similar size is placed across the front of the chest, moulded to the contours of the chest and held in position by a few turns of bandage. As the patient leans back he secures the posterior electrode, he may also hold a pillow against the front one. (Fig. 150.) A current of 1000 to 1500 milliamperes is applied for twenty to thirty minutes. In pneumonia and in other conditions where the patient is in bed the posterior electrode may be slipped under the back by simply depressing the mattress; the anterior one is covered by a thick towel and may be held in firm contact by the hand of the nurse or by a fairly light sandbag. The position of the electrodes can be varied so as to place the affected lobes in the shortest path of the current. It may be advisable to alternate antero-posterior application with bilateral ones (cross-fire diathermy), by placing the plates in the axillary regions.

Fig. 168.—Treatment of chest by pancake coil.

Abdominal Organs.—Treatment to the stomach, gall-bladder, liver or to the intestines is applied with the patient in dorsal recumbency. The relative size and position of electrodes must be varied according to the size and depth of the organs to be treated. The *gall-bladder* may be treated by a smaller condenser electrode placed in front and a larger plate under the back. In body treatments administered to the patient in the reclining position, cognizance must be taken of the fact that the weight of the body slightly diminishes the dielectric spacing of the posterior electrode. For increased depth effect considerable spacing or large electrodes must be used. In using long-wave diathermy a 4 by 5 inch or smaller plate, according to the size of the individual, is placed over the organ to be treated and a plate of similar size is placed under the back opposite to the anterior plate. A folded towel or small pillow may be placed under the back so as to insure even contact. The anterior plate may be held by a bandage, or by a small sandbag, or by the patient's hand resting on a thick folded towel placed over the plate. Current toleration ranges from 1000 to 1500 milliamperes; duration of treatment should be half an hour or more.

In treating *kidneys* electrodes of equal size and shape are placed over one or both kidneys, and connected to one terminal, while a dispersive electrode, 5 by 6 inches or of a size corresponding to the size of the two kidney electrodes is placed upon the abdomen. Patients are best treated while lying on the stomach. A current from 1000 to 1500 milliamperes is employed.

Male and Female Organs.—For techniques see Chapters on gynecological and genito-urinary conditions.

Rectal Diathermy.—The metal contact plate technique is the most efficient for treating the rectum and prostate. For long-wave diathermy, an active electrode is inserted into the rectum and the dispersive electrode is placed above the symphysis. The size and shape of the active electrode depends on the condition to be treated. In ordinary cases the regular cylindrical prostatic electrode will serve; in cases of spasm of the anal opening cone-shaped electrodes of suitable size are employed; in relaxed cases a flat rectal electrode tapered at its base may be used. For treatment of strictures special sized and slightly curved electrodes have been constructed. The active electrode is held by sandbags or elastic bandage suitably fixed to the electrode. From 1000 to 1200 milliamperes of current should be employed; patients as a rule report only a mild sensation of heat in the anus with such a current strength.

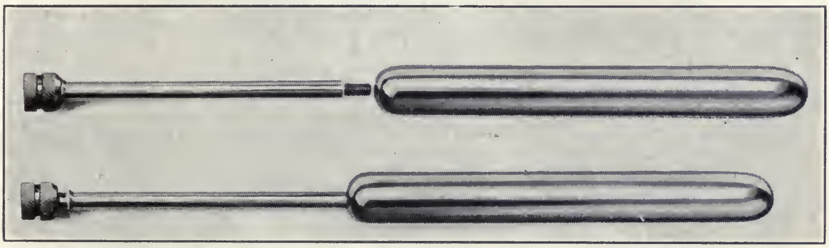

FIG. 169.—Electrodes for rectal diathermy. (Frankfeldt.)

Shoulder and Upper Extremity.—The irregular contour of the shoulder presents quite a task for efficient and comfortable application of diathermy. As a general rule, in order to relax all structures, the patient should be reclining on a treatment couch with the arm abducted and propped up by supporting pillows. Short-wave treatment may be given by a pancake coil or loop placed over several layers of toweling or by spaced plates held antero-posteriorly by treatment arms. Condenser pads may also be applied antero-posteriorly or laterally. For treatment of both shoulders a circular cuff electrode may be placed round the middle of each arm. For concentration over the subdeltoid bursa a smaller condenser pad or spaced plate may be placed over the region of the bursa and a large dispersive pad or plate held over the lateral chest wall of the opposite side.

For long-wave diathermy application can be made antero-posteriorly with electrodes of equal size, from 2 to 3 inches square or $2\frac{1}{2}$ inches wide and 4 inches long, placed opposite each other and equidistant; for longitudinal application, acutely painful shoulder conditions, such as brachial neuritis and subdeltoid bursitis, one-half cuff malleable plate electrode is held across the upper edge of the trapezius; another electrode of the same size and shape is placed across the middle of the upper arm.

Simultaneous treatment of both shoulders may be employed in bilateral arthritis or bursitis by two suitable shaped plate electrodes, and held by elastic bands; this technique has practically no effect on chest structures.

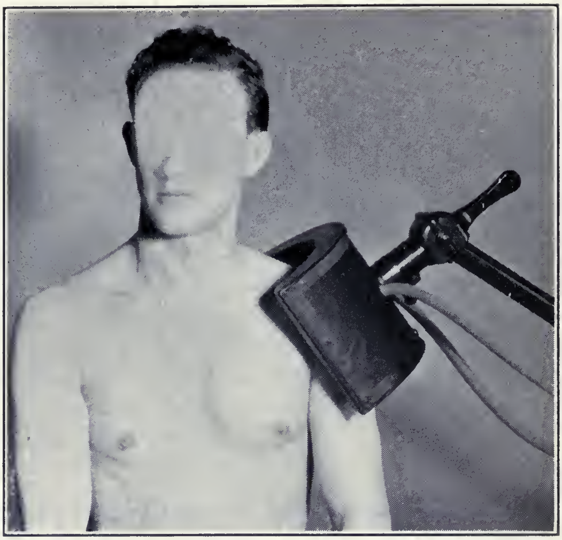

Fig. 170.—Curved disc applied to shoulder. (Courtesy of Liebel-Flarsheim Co.)

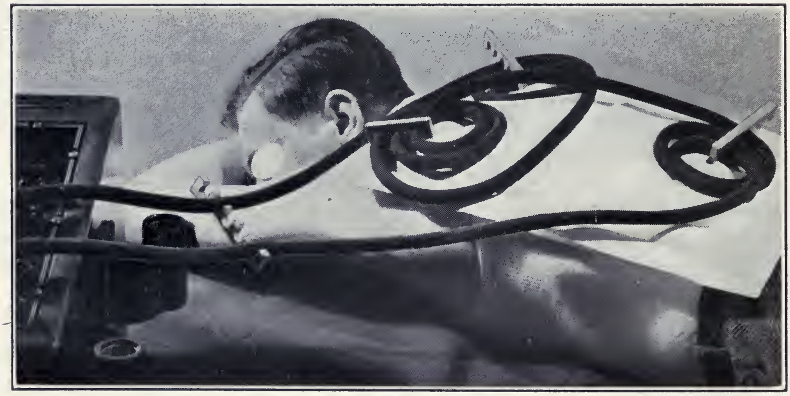

Fig. 171.—Treatment of shoulders and lower back by pancake coil.

Fig. 172.—Longitudinal heating of upper extremity by condenser pads.

Elbow.—Treatment may be rendered by an inductance cable wrapped round (Fig. 158) or by cuffs applied above and below the elbow or, finally, by semiflexible condenser pads applied laterally. When the elbow cannot be fully extended the cuff method of heating should not be applied, as it will lead to undue current concentration on the flexor surface of the joint. For long-wave treatment the transverse position of electrodes is most suitable.

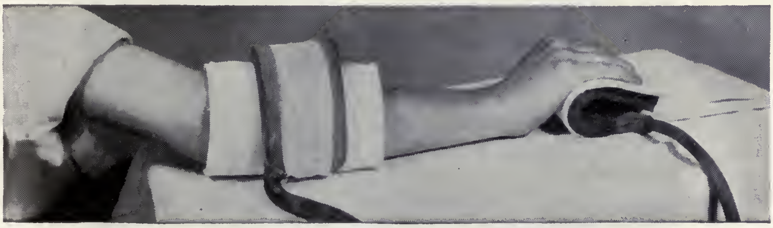

Fig. 173.—Wrist treatment by cuff and pad.

Wrist and Hand.—The inductance cable method is quite effective, either in the form of a loop wound round the parts or with the hand placed over a pancake coil. The hand also can be treated by being placed between two large flexible condenser pads. Fingers can be heated jointly or singly by being placed in contact with one condenser pad, while the other pad is placed behind the arm, the elbow being held in flexion.

Fig. 174.—Wrist treatment by two condenser pads.

For the treatment of the entire upper or lower extremity either an inductance cable or the circular cuffs can be employed. Cuffs should be as far apart as possible, with a minimum of skin-electrode distance. Two condenser parts may also serve as shown in Figure 174.

For long-wave treatment of the wrist, electrodes may be placed on its opposing surface or a cuff electrode is placed around the middle of the forearm while a cylindrical electrode is held in the patient's grip or the patient's fingers are placed in a water bath. In treatment of the hand and fingers the whirlpool or paraffin bath is much simpler to apply and causes a more even distribution of heat.

Fig. 175.—Diathermy to hand and wrist by water bath and cuff method.

Fig. 176.—Transverse heating of both knees by condenser pads.

Hip and Thigh.—Flexible condenser pads or spaced plates may be applied antero-posteriorly with the patient lying down. The pancake coil technique can be also employed, by placing a few turns of the inductance cable directly over the region to be treated. For long-wave treatment, two large size (4 by 6) electrodes are placed antero-posteriorly, one above Poupart's ligament, held by a sandbag and the other under the gluteal region, held by the body. A current from 1200 to 1500 milliamperes should easily be tolerated. For the thigh, either antero-posterior or latero-transverse application can be made.

Knee.—The knee should always be treated with the patient on a table or couch or in a steamer chair with the foot rest raised. The inductance cable is quite convenient using several turns wound around the knee. (Fig. 152.) The same technique can also be employed for treating two knees simultaneously. One may use a cuff above and below the knee. Finally condenser pads or spaced plates may be placed laterally.

For long-wave treatment, two broad cuffs, 3 inches wide, are applied one around the middle of the thigh, the other around the middle of the leg and held by a few turns of elastic bandage.

FIG. 177.—Treatment of ankle by coil method. (Courtesy of General Electric X-ray Corp.)

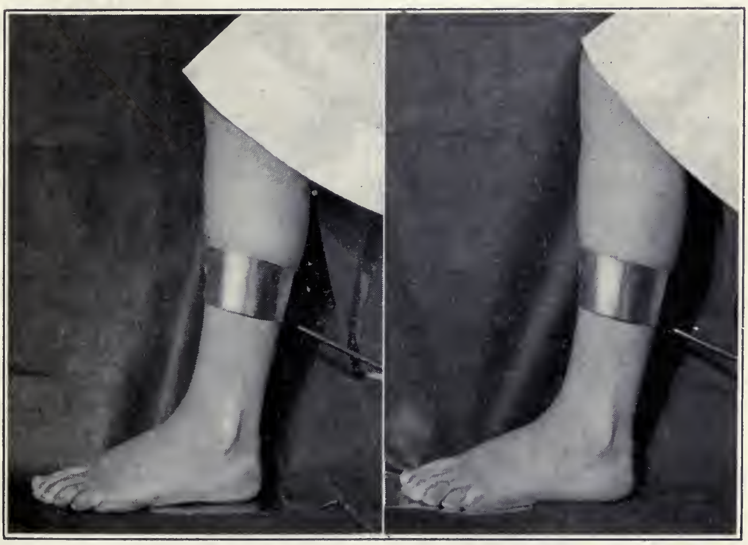

FIG. 178 FIG. 179

FIG. 178.—Diathermy to ankle and heel (cuff and plate).
FIG. 179.—Diathermy to forefoot (cuff and plate).

Ankle and Foot.—The ankle can be treated by condenser pads or spaced plates placed laterally or an inductance cable wound around it. It may be also treated by a condenser pad under the heel and foot and a circular cuff placed around the middle of the leg. The foot can be treated by similar technique. Both feet and legs can be warmed up by pad electrodes placed under the sole of each foot. It is important that both electrodes be kept at suitable distance from the floor to avoid loss of energy due to semi-conductors.

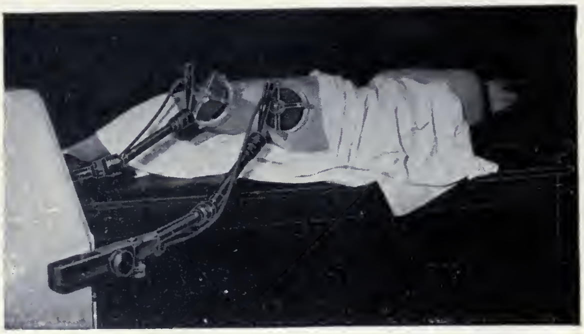

Fig. 180.—Air-spaced treatment along course of sciatic nerve. (Courtesy of McIntosh Electrical Corporation.)

For long-wave treatment, if the ankle is much enlarged the lateral transverse method may be used, placing two oval electrodes about 2 by 3 inches on either side of the joint. On account of the irregular bony prominence of the malleoli, it is more convenient to use the combination plate and cuff method.

Safe and efficient heating of all structures of the foot can be accomplished by hot foot baths, especially the whirlpool bath, or by an inductance coil. In another method, a plate is placed under the forefoot and a cuff around the leg as illustrated; a current strength from 300 to 500 milliamperes may be employed.

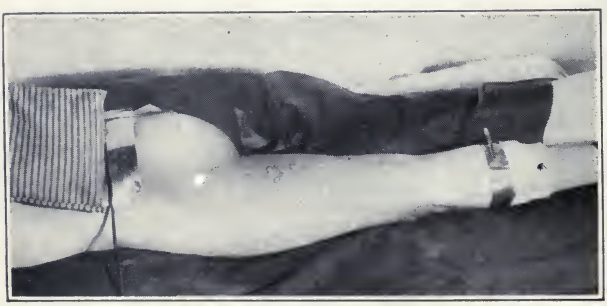

Fig. 181.—Diathermy to sciatic nerve (longitudinal).

Sciatic Nerve.—Short-wave diathermy may be applied by an inductance cable wound around the lower extremity, by two condenser pads or air-spaced plates: one placed over the lumbar or gluteal region, the other on the posterior aspect of the thigh just above the knee. After twenty minutes treatment this electrode is moved to the middle of the calf, and twenty minutes more treatment applied. A cuff electrode placed around the calf may be also used as the lower electrode.

For long-wave diathermy a similar procedure can be used by contact plates, as shown in Figure 181. Transverse heating may be accomplished by a narrow plate about 2 inches wide and 4 to 6 inches long, placed directly over the course of the nerve, with a dispersive electrode of slightly larger size placed on the opposite surface of the groin or thigh. This is the only really penetrating treatment. The longitudinal method only acts indirectly by warming up the surrounding muscles and other soft parts. Clinically, either method appears effective in most instances.

Safety Rules in All Diathermy Treatments.—In addition to the general rules for electric treatment in Chapter VI, the following special rules are to be observed in applying all diathermy treatments:

1. Before applying electrodes inspect carefully the parts to be treated to make sure that the continuity of the skin is nowhere broken and that the heat sensation of the patient is normal. In case of scar tissue, peripheral nerve injuries, of hysterical anesthesia, be extremely careful in the application of diathermy.

2. Before turning on the current from the main inlet inform the patient that the sensation to be expected is that of mild heat. Instruct the patient to report any uncomfortable faradic sensation, pricking or burning at once.

3. After starting the current through the main switch, open up gradually first the current regulator (rheostat) and then the spark gap in long-wave apparatus. Only practical experience will teach how to manipulate this double control properly. In some short-wave apparatus one control serves to regulate the current; in others, first a separate tuning control must be set.

4. Do not try to push the current up to the maximum amount of toleration during the first few treatments. Patients often are burned in their endeavor to show how much current they can stand. Remember the principle that a moderate amount of heat applied for a longer period is more effective than pushing up to the limit of tolerance for a shorter period.

5. If at any time during the treatment the patient complains of an uncomfortable sensation anywhere turn off the controls, shutting off the main current inlet in case of emergency and, if necessary, take off, inspect and reapply the electrodes. When inspecting or adjusting electrodes be sure that the current is turned off and increased gradually again after such a procedure.

6. Do not leave the patient alone during treatment unless you have arranged that by the simple pulling of a cord or the turning of a switch the patient himself can turn off the current at any time. Watch the milliampere meter during the entire treatment for an even flow of the current.

7. At the end of the treatment turn off the controls in the reverse order to which they have been turned on. This will leave all the switches and controls in safe position to start the next treatment. Take off the electrodes carefully and inspect the site of application each time.

8. Let the patient rest after treatment long enough to make sure that the skin has fully cooled off, especially in inclement weather.

Correct application of diathermy in the various conditions to be enumerated can only be acquired through ample clinical instruction. It is not fair to reputable manufacturers to expect their salesmen to be instructors in technique. The safe and efficient use of diathermy does not consist simply in applying a pair of electrodes and then snapping on a few switches. Poor results and at times law-suits for malpractice on account of burns have been the outcome of attempted short cuts from manufacturer to physician, leaving out the intermediary of required instruction in the clinic.

Special Precautions With Short-wave Diathermy.—In applying short-wave treatment, metallic objects, such as hair pins, safety pins, buttons, keys, knives, watches, buckles should be removed from the field of treatment because they lead to a concentration of electrical energy and the possibility of arcing and burns. Metallic chairs or tables, radiators, water pipes, electric fixtures or other grounded metal should not be within possible contact with the patient, neither should conducting cables make contact with such objects. Hence it is preferable to use treatment tables and chairs without metallic parts, and use mattresses without inner metal springs.

Special care must be taken that no cables leading to the apparatus cut across each other or get too close to each other, because this may lead to overheating of their insulation and possible conflagration. This danger does not exist when using contact metal electrodes with apparatus with extra condensers.

Like all other electrical treatments short-wave diathermy should be applied to the unclothed body only, contrary to some ill-advised early assertions that this method enables treatment through clothing. Application of electrodes over the clothed parts breeds carelessness in neglecting the elementary rule of close inspection of the parts before and after every treatment; also the varying thickness of clothing may interfere with correct spacing of the electrodes. Hidden metal objects as well as unsuspected moisture in the clothing are also potential causes for burns.

SPECIAL TECHNIQUES WITH LONG-WAVE DIATHERMY

General Diathermy.—The object of general diathermy is to administer a current of sufficient intensity to bring about a mild rise of body temperature. A current from 1500 to 3000 milliamperes is necessary for such purpose and it requires apparatus of sufficient capacity to produce such current for an hour or more without overheating. General diathermy may be applied by the three plate method: the patient reclines over a large electrode under his bare buttocks; another plate 6 by 6 inches is placed under his shoulders and a third one under the calf of the legs; the two outside electrodes are jointly connected to one terminal, the middle electrode to the other terminal. Another arrangement is the one used for the original hyperpyrexia treatment by diathermy: one electrode is applied to the chest, another to the abdomen and these two are connected to one terminal, while one large plate corresponding in size to the two former ones is placed under the back and connected to the second terminal.

General diathermy may be useful in selected cases of chronic arthritis, and in mild degrees of arteriosclerosis.

Autocondensation.—Autocondensation is a modified form of general diathermy. One or two electrodes (metal cylinders or plates) are applied by direct contact to the palms, soles, forearms, or chest, and connected to one terminal of the apparatus, while another very large electrode known as an autocondensation pad and consisting of a large plate separated from the body by insulating material (fiber), is connected to the other terminal. When the current is turned on the body becomes one part of a condenser, and the metal plate under the pad is the other. If a glass vacuum electrode, grounded through the operator's hand, is held at some distance from the patient under treatment, it will light up and prove the presence of an electric charge all over the body. In the early days of high-frequency treatment the specially constructed autocondensation chair of DeKraft was quite popular. Current from 500 to 1200 milliamperes may be employed for ten to thirty minutes depending on the condition and the type of apparatus and technique used.

FIG. 182.—Autocondensation pad. (Courtesy of Westinghouse *X*-ray Corporation.)

Autocondensation produces local heating where the electrodes are directly applied and also slight general heating if the treatment is continued long enough and the apparatus is sufficiently powerful.

The physiological effects of autocondensation correspond to those of general diathermy. In patients with high blood-pressure without marked cardio-vascular changes or in the early stages of arteriosclerosis, there often occurs a drop in blood-pressure of from 5 to 10 millimeters, hence the long-standing popularity of this method in treatment of hyperpiesis (see Chapter XXIV). It is also useful in treatment of functional neuroses and nervous insomnia.

The autocondensation chair or pad may also aid in *diathermic massage* as described by Turrell:[30] when a patient placed in the autocondensation chair is approached by the operator's fingers, the operator being grounded, attracts the current from the patient's capacity. Gentle stroking of the painful superficial area imparts a pleasant sensation of warmth, which is very soothing, especially in acute facial neuralgia.

Monoterminal High-frequency (Oudin) Treatment.—Because of the recent interest in short-wave diathermy, the medical employment of the Oudin current has been almost forgotten, in contrast to its continued surgical use for electrodesiccation. Yet the Oudin treatment has some very definite clinical usefulness and therefore deserves to be retained in our physical therapeutic armamentarium.

In administering Oudin treatment the glass vacuum or condenser electrode is attached to the high voltage (Oudin) terminal and is held close to the part to be treated. The current strength is regulated by the combined use of the voltage control and spark-gap control; while the length of sparks is regulated by varying the distance of the electrode from the skin; thus a variety of effects can be produced.

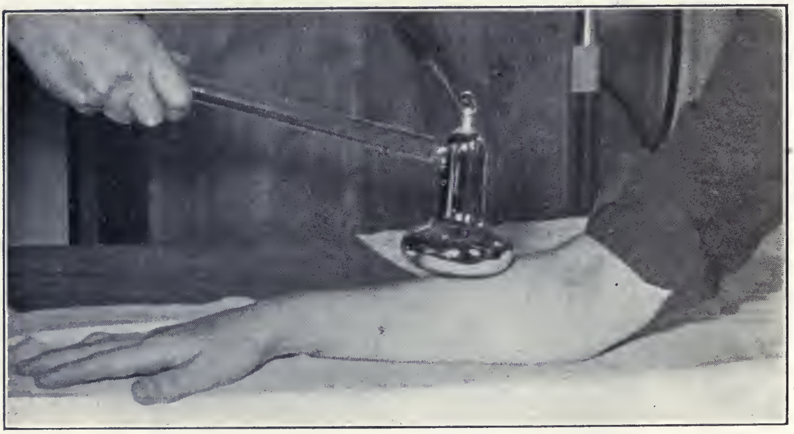

FIG. 183.—Treatment with Oudin current through glass condenser electrode.

Mild surface heating occurs, when the electrode is held in close contact over an area of the skin for some time. Counterirritation over a larger area may be produced by moving the electrode back and forth in only slight contact with the skin so as to cause definite sparking. Longer sparks and a stronger current cause a marked erythema which often lasts for hours. Gentle stroking massage is exerted when the electrode is kept moving. A very weak current may bring about a mild antipruritic effect.

The high-voltage current has a tendency to penetrate the insulation of the conducting cord when the electrode is lifted off the skin, operators should therefore hold the cord in a folded towel or wooden handle. Dusting talcum powder over the area insures a smooth moving about of the electrode.

Mild sparking with the electrode held fairly close exerts sedative effects on neuralgias of the skin nerves and on other superficial nerve irritations. A heavier spark discharge causes a marked stimulation of the vasomotor nerves and may serve as a counterirritant for relieving deeper seated muscular pain or neuralgia.

To tender areas of the skin the Oudin current may be applied through the operator's finger tips; by making the patient hold a metal cylinder connected to the Oudin terminal, he is being charged by the high-frequency current and the finger-tips of the operator will draw a shower of mild sparks along tender spots. This is similar to diathermic massage.

Sparks may be drawn from a patient in contact with a condenser electrode during Oudin treatment if approached by a grounded metal tip and "indirect desiccation" may thus be performed.

Clinical Uses.—(*a*) The Oudin current is very effective for the relief of pain in neuralgias of the skin nerves, such as of the intercostal, supraorbital, occipital and ulnar nerves and in meralgia paresthetica, a painful affection of the nervus femoris cutaneus lateralis. It is also useful in other forms of neuralgia and neuritis such as brachial neuritis and postoperative scar neuralgias. One should commence with a sedative technique, *i. e.*, a mild current strength, a minimum of sparking effect and treatment time of from five to ten minutes and gradually increase these according to the relief produced. Preliminary heating by an infrared or luminous heat radiator is helpful. Treatments are repeated daily in acute pain.

(*b*) In the treatment of recent traumatism such as contusions, traumatic myositis, sprains and in the deep-seated chronic pain of sciatica, lumbago, and tenosynovitis, fairly vigorous sparking by the Oudin current for ten to fifteen minutes often renders instantaneous relief through counter-irritation. It is also advisable to precede these applications by luminous heat or local diathermy.

(*c*) In sluggish ulcers and selected forms of low-grade skin infections high-frequency sparking exerts mild bactericidal, antipruritic and stimulating action. Anal fissures and pruritis, sluggish wounds about the anus and vulva may also be benefited.

(*d*) In hay fever a few minutes daily application of the Oudin current to the nasal mucosa may give symptomatic relief. This has been explained by "desensitization" of the mucous membrane. It has been recommended to combine this treatment with vigorous sparking up and down the spine for the "revulsive" effect.

(*e*) In functional neuroses or in minor degrees of chronic inflammatory changes of inner organs, vigorous sparking of the corresponding skin areas (Head's zones) may bring symptomatic relief. This has been attributed to reflex stimulation through the vegetative nervous system. Such action explains the occasional relief lay people find from "violet ray" treatments self-applied through glass electrodes activated from a cheap imitation high-frequency coil.

Combination of Low-frequency Currents With Diathermy.—The simultaneous application of low-frequency currents for muscle stimulation and long-wave diathermy for heating as reported by the author[25] is based on definite physiological considerations. A heating current when applied to a congested body area, which may contain unresolved inflammatory exudates, may cause a relief of symptoms, but the material of congestion may not be eliminated and carried away. In such cases a supplemental mechanical agent may further promote repair. The routine method of treatment in traumatic and arthritic conditions in following thermal measures by mechanical ones, is based upon this principle. Muscle exercise is best carried out after preliminary heating. Since a rise of temperature in the tissues brought about by any form of heating will begin to subside as soon as the heating agent ceases to act, it appears advantageous from the standpoint of efficiency as well as of saving time to apply thermal and dynamic measures in certain conditions simultaneously.

The physical principle enabling combined administration of high- and low-frequency currents is a double filtering device which (1) prevents the flow of the diathermy current into the low-frequency generator by a suitable impedance (choke-coil) and (2) prevents the flow of the low-frequency current into the diathermy circuit by condensers. A coil of thick wire consisting of closely adjacent turns interposed on the low-frequency side offers an effective impedance to the high-frequency current but offers only a minute resistance to the low-frequency current. A set of condensers on the high-frequency side between the resonator and the binding posts prevents an overflow of the low-frequency current but does not impede the diathermy current. Such a device can be incorporated into an apparatus containing the two types of generators or can be employed as an independent unit in conjunction with any make of long-wave diathermy and low-frequency apparatus.

With the described arrangement both currents can simultaneously be delivered to the patient from the same binding posts.

In the *technique* of applying the combined current moist pad electrodes are employed in order to obviate the possibility of a burning sensation due to the slight polarity effect of the low-frequency current. Diathermy metal can be converted into a suitable electrode by interposing 12 to 16 thicknesses of moist gauze between the plate and the skin. For treating the extremities, the hand or foot may be placed in a water-bath and a circular cuff or semicuff employed around the arm or thigh. The longitudinal technique of application is the rule in order to carry out group stimulation of muscles. For vaginal or rectal administration, the ordinary metal electrode is satisfactory and the author has found that in a number of cases even plain metal electrodes on the skin such as metal footpads are well tolerated. For trans-abdominal treatment large moist-pad electrodes are employed. Applying diathermy through moist pads increases the resistance in the circuit considerably and also introduces a relative danger of a burn, due to the drying out of the gauze pad in spots.

It is advisable to start with the diathermy current and after it has flowed for five to ten minutes and the parts have begun to become warm, turn on the low-frequency current. In cases of peripheral nerve injury, special precaution is necessary to avoid burns by diathermy.

Clinical Uses.—The author has employed the combination of diathermy with the surging faradic or modulated alternating current with satisfactory results in the following conditions: (1) in subacute and chronic forms of arthritis, in which there is joint pain and muscular stiffness (longitudinal technique), (2) in peripheral nerve injuries (slow sinusoidal if there is RD present), (3) in abdominal adhesions (transverse technique), (4) in chronic prostatitis (metal electrode in rectum, large moist or metal pad over abdomen), (5) in adhesions and stiffness following infections or vasomotor disturbances of the extremities.

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CHAPTER XII

HYPERTHERMY

General Considerations. Methods. Hydriatic Methods. Electrical Methods. Physiological Effects. Bactericidal Effects. Clinical Uses. Gonorrhea and Its Complications. Syphilis. Other Conditions. Contraindications. General Technique. Preparation. The Inductance Period. The Maintenance Period. Complications.

General Considerations.—The production of fever for the increase of the protective and defensive mechanism of the body has taken a definite place in modern therapeutics. Following the original method of malarial inoculation for fever production a number of methods have been developed for raising body temperature such as by inoculation with typhoid vaccine and other substances as well as by various physical methods. It has been recognized that in the clinical results achieved, the sustained temperature elevation in the body is the important factor.

Electrical methods of raising body temperature were the first to be applied generally, and for these the term electropyrexia has found general acceptance. However, equally good results can be obtained by other physical methods and the term of artificial hyperpyrexia or hyperthermy is therefore more suitable because it is all inclusive. The advantage of hyperthermy over other therapeutic fever methods is that it is sterile, always available and the intensity of the febrile reaction is under accurate control. Different pathological conditions require different degrees of hyperthermy: there is no uniform scale of hyperthermy applicable to all cases. The physiological consideration, indication and contraindications and various phases of hyperthermy are principally alike in all methods. For practical reasons the entire subject matter will be presented in this chapter.

METHODS OF INDUCING HYPERTHERMY

Hyperthermy by physical means is brought about partly by supplying the body with a suitable amount of extra thermal energy from without and partly by preventing heat loss from the body.

The temperature of the human body can be raised by external forms of heating which primarily heat the skin and in turn affect the inner organs *via* the blood stream and deeper circulation. Among these belong the various hydriatic procedures, heat radiation from luminous and infrared sources and circulating superheated air. Penetrating forms of heating effect more of a general heating of all body tissues. These consist of long-wave diathermy and short-wave diathermy. The body temperature can be raised equally efficiently by both forms of heating.

In the heated body the heat regulating mechanism attempts to bring about heat loss, partly by radiation and partly by vaporization of water from the skin and lungs. Regardless of the method of heating used, careful attention must be given to prevent heat loss from the patient if a fever temperature is to be maintained for a number of hours. During the stage of evolution tight wrapping of the body with blankets or placing it in an insulating "zipper" treatment bag was employed but both methods were largely discarded because of the discomfort of close confinement, the irritation of excessive perspiration and the inability to satisfactorily observe the patient's skin during the entire treatment time.

Cabinets are considered the most satisfactory method for the prevention of heat loss; in these the surrounding temperature is maintained at a level above fever temperature, usually by hot humidified air; as a matter of fact one of the most efficient types of fever apparatus consists of nothing else but an "air-conditioned" cabinet. The chief advantage of cabinets is that the patient is free to move and thus more comfortable. There is less likelihood of a burn and all parts of the unclothed body can be observed during treatment through either a transparent window or side openingst

Hydriatic Methods.—A hot water bath is undoubtedly the simples. means for quick elevation of body temperature, but is neither comfortable nor safe. The patients may be immersed in a full bath at 105° F., the

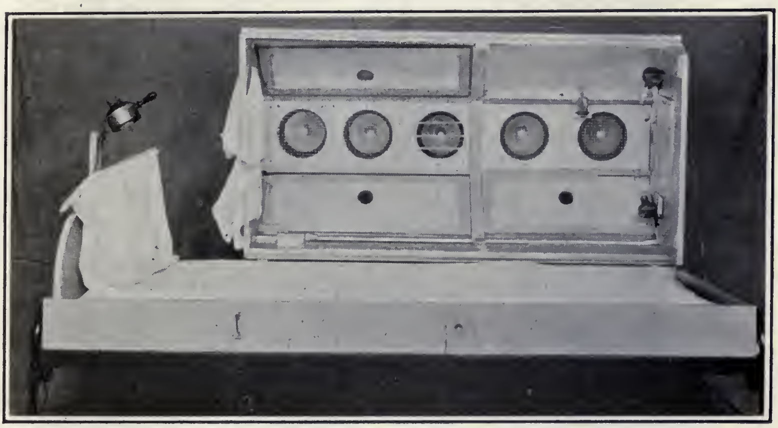

Fig. 184.—Luminous heat cabinet. (Courtesy of Dr. Stafford L. Warren and Journal of the American Medical Association.)

water temperature is gradually raised to 110° F., and the patient kept in the tub until his temperature is within 1.5° of the desired height. This method has only been found practical for short and low fevers. Hot water bottles placed around the patient wrapped in heavy blankets may serve as another simple but most uncomfortable hydriatic method. Hot vapor or steam or hot-water spray cabinets are more efficient; for the last procedure a somewhat elaborate apparatus is available, in which the temperature is raised by a spray of nebulized hot water. A thermostatic control serves to maintain the water temperature, and also enables a quick shift to a spray of cool water to refresh the patient momentarily without impairing the temperature rise.

Electrical Methods.—*Electric blankets* consist of a large number of properly insulated wires incorporated with rubber, the temperature of the blankets being controlled by a rheostat. These blankets are less expensive than other fever apparatus; however, not alone is their close confinement uncomfortable to the patient, but in poorly constructed and non-moisture proof blankets, there is also a definite danger of short circuits and fire to the blanket.

Luminous heat cabinets consist usually of a box of celotex or wood, fitting over a table or hospital bed, or it may be a single unit. A number of carbon filament lamps (5 to 6) of a wattage of 100 to 200 are wired in the top of the box and controlled by a rheostat. The patient is placed in this box with his head protruding from one end through an opening around which suitably shaped cloth or soft rubber insulation serves to prevent heat loss. In most cabinets sliding doors at the side allow access to the patient at all times. Bishop, Lehman and Warren[5] state that heating by radiant energy is the most convenient and economical method. (Fig. 184.)

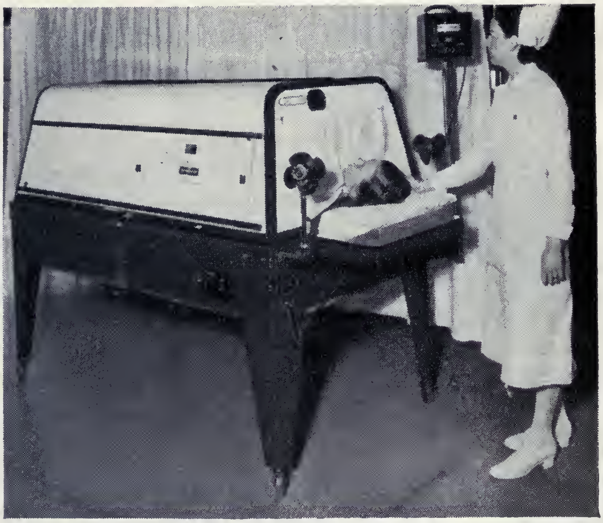

FIG. 185.—Air-conditioned fever cabinet. (Courtesy of The Liebel-Flarsheim Corp.)

Non-luminous heat cabinets are similar in construction to the electric light cabinets but are heated by resistance coils, usually placed at the bottom of the cabinets from which the heated air ascends. There is available a simple hot-air cabinet containing a shallow copper trough filled with water at the bottom of the cabinet, which is kept simmering by a flat coil heater in addition to three large 600-watt heating elements. This cabinet supplies humidified air at a temperature varying from 120° to 130° F. (Atsatt[1]).

The *air-conditioned cabinet* developed by Simpson, Kettering and Sittler is an apparatus in which air temperature, relative humidity and air velocity may be fully controlled. (Fig. 185.) The walls of the cabinet are heavily insulated and rust-proof. There are two chambers in the cabinet. A large one, for the patient, has a semicircular portion cut out for the patient's head and neck; a small chamber at the foot end contains the air conditioning mechanism, consisting of the heater, humidifier, blower, thermostat and a humidostat, all operated by electrical current. The heating element is a resistance unit of 1550 watts, controlled by the thermostat. The humidity is secured by a pan of water heated by a 2000-watt electrical immersion heater. The water level is maintained by a reservoir placed outside the cabinet and regulated by a self-feeding water system. Humidity is regulated by the humidostat and is checked by dry- and wet-bulb thermometer readings. The air thus heated and humidified is circulated through the upper portion of the chamber by the blower. The air is forced through the holes at the head end of the cabinet and returns by the grill at the foot end. The circulation is adjusted to a change of about 10 times a minute or an air velocity of 200 cubic feet per minute.

General diathermy by the long-wave method was first reported on by Neymann and Osborne[21] and was applied by special apparatus with about double the output of the ordinary long-wave machine. Large flexible metal electrodes were applied antero-posteriorly on the body and held by a tight fitting canvas jacket. The modern, safer and infinitely more comfortable short-wave diathermy methods using cabinets have made this method obsolete.

Condenser Field Heating.—In this method as first developed by Whitney[32] patients were placed between two large condenser plates activated by a short-wave apparatus producing 30 meter waves. The patient was surrounded by blankets or placed in an insulating zipper bag. Due to accumulation of perspiration, which acts as a condenser of the energy over some areas, burns occurred frequently.

FIG. 186.—Combination of luminous heating and spark-gap condenser field heating for electropyrexia. (Courtesy of the Lepel High Frequency Laboratories.)

Recent types of condenser field fever apparatus employ large electrodes held by suitable treatment arms above the patient's body. The author for a number of years has used most satisfactorily a home-built cabinet which contains on top a double row of 150-watt bulbs controlled by a rheostat. Two large condenser plates connected to a short-wave apparatus are held in a grating above the patient (Fig. 186). The placing of air-spaced electrodes above the patient aims to prevent condenser effects on accumulated moisture and subsequent burns. After the induction period the short-wave energy is turned off and cabinet temperature is maintained at 110° F. by burning of the light bulbs.

Coil Field Heating or Inductothermy.—General body heating is being efficiently accomplished by inductance cable wound around the patient or held in a form of a single loop either above or below the body; this cable is connected to the short-wave diathermy machine. Such arrangement is normally provided in connection with a metal fever cabinet in which the patient lies on a special type of mattress. Suitable humidity is also maintained by a water container, fillable from the outside, a water heater and a fan.

There are also available *combination fever cabinets* which provide air conditioning within the cabinet itself, both humidity and temperature being controlled; at the same time the cabinet is wired for coil field heating, which enables a lower cabinet temperature in the initial stage of the treatment, only one or two degrees above the required patient's temperature.

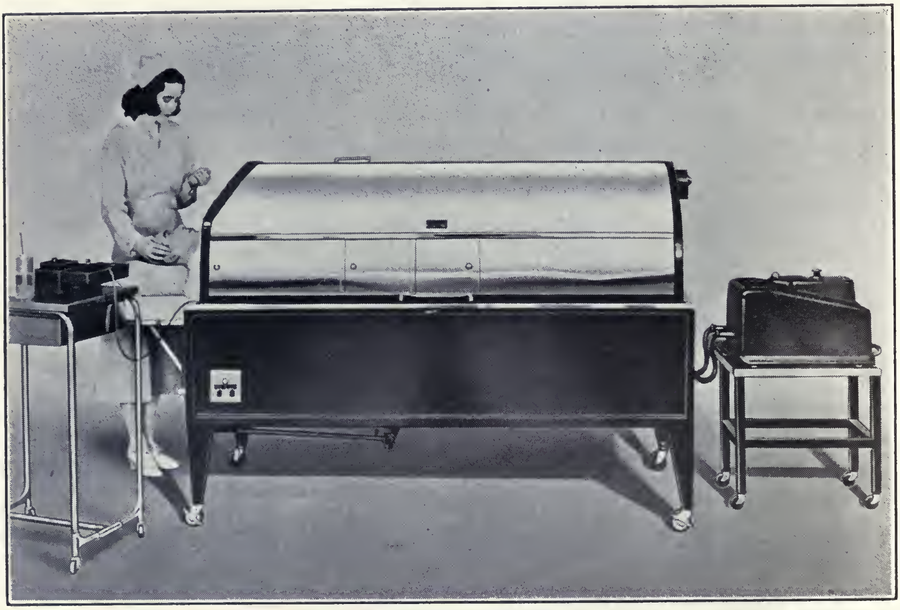

Fig. 187.—Inductance cable heating in fever cabinet. (Courtesy of the General Electric *X*-ray Corporation.)

In spite of the great variety of efficient and elaborate fever therapy apparatus available one must emphasize again with Simpson[27] that the skill of personnel far transcends the perfection of apparatus and that the worst possible apparatus managed with skill and the best possible technique is much more likely to give good results than an excellent apparatus placed in unskilled hands. One factor of equal importance is the careful selection of cases.

Requirements for Fever Apparatus.—In discussing the evidence required by the Council on Physical Therapy for consideration of apparatus used in fever therapy, it is stated:[8] "The most acceptable device would seem to be of the cabinet type, so arranged that the patient during the treatment and his physical needs can be attended to conveniently. The only accurate way of keeping close check on the temperature of the patient is by using the rectal thermometer. Hence, means should be provided to read the temperature conveniently. The unit must be so constructed that the patient may be withdrawn with facility, in case of emergency, and restorative treatment administered. The Council emphasizes the convenience and safeguards attached to apparatus as fully as it does the physical claims made for such apparatus. The paramount question is not so much one of the most suitable methods of raising the body temperature as of the safety to the patient with any particular method."

PHYSIOLOGICAL EFFECTS

Artificially produced fever causes marked changes in the physiologic functions of the body. To a certain extent these changes are an intensification of those following mild general heating of the body and shown in the comprehensive table by Bazett (see Table 26). The close observation of these changes during the entire treatment period is the best safeguard against untoward physio-pathologic complications leading to collapse and possibly death.

The pulse-rate increases with the rise of temperature but there is no generally accepted fixed rule regarding this increase. With the temperature maintained at a given level for a considerable period, the pulse-rate may rise or fall. Any sudden rise of this rate as the temperature is being prolonged or a marked rise of the pulse as the body temperature is rising, must be regarded as a definite sign of danger. A rate of 160 or more should indicate that the danger zone is being reached.

The blood-pressure shows usually first a slight elevation of the systolic level and a decrease of the diastolic pressure to 60 to 50 mm. With the rise of temperature the circulatory rate is greatly increased, with a maximum increase between 103° and 100° F., and there is a marked increase in the pulse volume in the fingers of the patient. The venous pressure may show marked fluctuations in either direction.

The number of red and white cells is increased. Leukocytosis occurs at the height of the fever with usually a high polymorphonuclear count and a relative decrease in the lymphocytes and monocytes. There is only a slight change in the blood chemistry. The blood plasma volume is decreased during artificial fever due to concentration of blood from loss of fluid by sweating.

The basal metabolic-rate increases at a rate of about 7 per cent for each degree rise in temperature. Every patient who has undergone five hours or more of fever treatment will lose from 4 to 5 pounds of weight, due to the fluid excreted by perspiration. The urine may be suppressed at the beginning due to sweating but the total output is usually normal. Specific gravity may be increased. The loss of chlorides through the perspiration may amount to 20 to 26 grams in one febrile session. All these changes return to normal after a few hours.

The loss of fluids through the skin, the lungs and the urine brings about a disturbance in the acid-base balance of the blood. This as well as the decrease of its carbon dioxide content brings about a pronounced alkalosis. The degree of alkalosis which approaches critical levels is dependent, primarily, upon the severity of dehydration and, secondarily, upon the extent of the hyperventilation. Hence the maintenance of a proper fluid intake during the treatment is vital, especially if long treatments are administered. In severe cases intravenous administration of fluid is indicated for the restoration of the diminished blood volume. Another important consideration is the maintenance of the chloride balance, requiring the administration of salt solution from the very beginning of treatment.

Placing the body in an environment of extremely high humidity (over 80 per cent) also minimizes the loss of fluids through insensible perspiration.

The relative physiological effects of external heating and penetrating heating have been studied by Neymann,[21] Phillips,[23] and Benson.[2] Neymann has shown that external heating reverses the natural temperature gradient of the body; during the rise of temperature the skin temperature mounts above the internal temperature and continues at this pathological level for some time after the fever temperature has been reached. Because

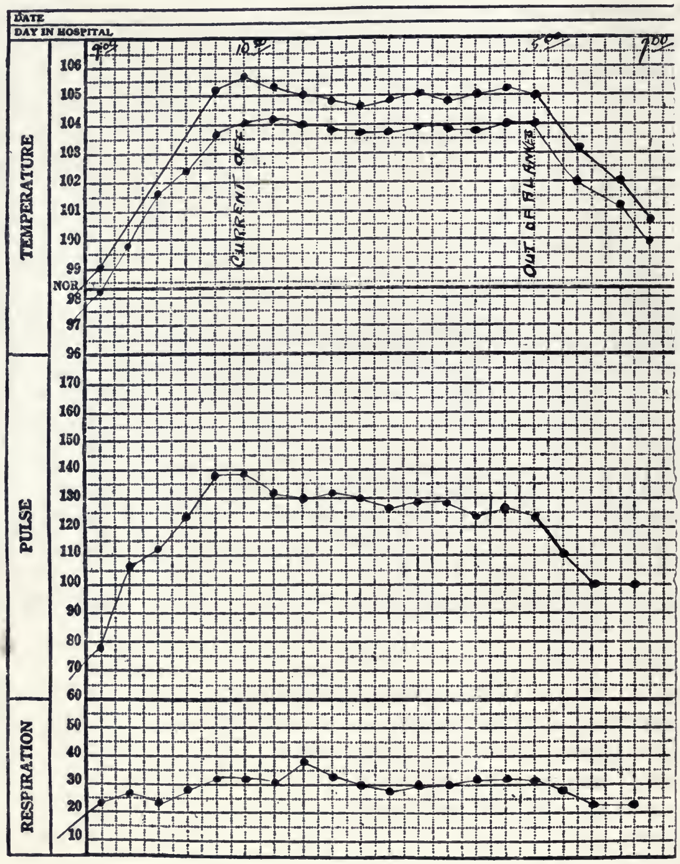

FIG. 188.—Typical fever chart in short-wave fever treatment. (New York Polyclinic Hospital.)

the heart-rate depends on the temperature of the skin it is decidedly higher when external heat is used to induce fever. The capillary pulse volume is also relatively increased by external heating while the amount of perspiration is relatively decreased. Because he considers external heating more exhausting Neymann favors electromagnetic fever induction. Phillips, corroborating the irritating effect of high external temperatures on the pulse-rate, recommends that if air-conditioned cabinets are used in combination with penetrating heat the cabinet temperature should be relatively low—105° to 110° F. and the saturation high, 85 to 90 per cent. Krusen[18] corroborated these findings with the newer technique of hot humid air cabinet technique, in which 130° F. is only maintained during the induction period and the cabinet temperature is then allowed to drop to 110° to 115° F. during the maintenance period. Krusen therefore concludes that the lowering of the pulse is not the result of the employment of internal heat, but of the relatively low environmental temperature and for this reason prefers to use the air-conditioned cabinet alone.

Bactericidal Effects.—Artificial fever treatment became recognized as a specific therapy when it was shown that it could destroy in the human body at least one very prevalent pathogenic organism, the gonococcus, without injury to the human host. The basic principle of this effect was clarified by the research of Warren *et al.*[29] They established that 99 per cent of all strains of gonococci were destroyed at a temperature of 105.8° F. (41° C.) in five hours whereas the remaining 1 per cent of gonococci required as much as twenty-three hours to be destroyed completely.

The thermal death time of Treponema pallidum was established by the same investigators at 106.8° F. (41.5° C.) in the laboratory at one hour. In humans with early syphilis these results are not so clear cut as in cases of gonorrhea.

Regarding meningococci, Moench[20] found some significant changes in reduction of growth after temperatures from 104° to 107.6° F.

Doan[11] calls specific attention to the tremendous increase of phagocytic cells in lymph nodes, spleen and liver following hyperthermy and concludes that it not only provides the thermal factor of importance for eradication of the gonococcus and the spirocheta pallida, but also exerts a powerful effect in the cellular equilibriums of the body. It acts as an "assistant extraordinary" to the humoral defense mechanisms of the body.

The presumable clinical benefits of fever therapy have been summed up by Hench, Slocumb and Popp[15] as follows: (1) A direct bacteriolytic or bacteriostatic effect due to the influence of heat itself on bacteria (without necessarily implying formation of immune bodies); (2) an indirect bacteriolytic or bacteriostatic effect resulting from increasing formation or mobilization of immune bodies; (3) a local effect from vasodilatation, providing an augmented blood supply to inflamed tissues, and (4) a general effect from the heightened metabolism incident to fever.

CLINICAL USE OF HYPERTHERMY

Fever therapy has undergone a period of enthusiastic experimental work in a large number of conditions, often without much rhyme or reason as to its clinical rationale. There can be no doubt that in gonorrheal infections it is of specific value, but even here, subsequently modern discoveries of chemotherapy have brought about a much more simple alternate. By this time the rationale and effectiveness of fever treatment has been definitely established in a limited number of conditions and has become part of standard therapeutic practice.

The list of the established uses of fever therapy in various conditions, with some comments will be given here; particulars, technique and detailed discussions of results will take place in the part on applied physical therapy.

Gonorrhea and Its Complications.—Warren[29] and his associates determined the "thermal death time" of an infective strain of gonococci at

106.7° F. and subjected the patient to the temperature sustained at this time. Practically 100 per cent cures have resulted from this procedure. The average length of fever treatments of Warren, Scott and Carpenter[30] was 14.8 hours. Other clinicians hold that in the great majority of cases such prolonged treatments are not necessary. Krusen, Randall and Stuhler[17] of the Mayo Clinic reported that with single ten-hour sessions at 106.7° F. negative cultures were produced in a high percentage of cases with gonorrhea. Desjardins, Stuhler and Popp[10] of the same clinic reported that in 90 per cent of cases three to six sessions at six to ten hours are sufficient to effect a permanent and complete cure. Bierman[3] doubts that there is an exact parallelism between the thermal death time of a particular strain of gonococcus *in vitro* with a fever of the same height and duration in its living human host. He states that the percentage of favorable results reported by those giving shorter treatments is about as good and that when the gonococci survive an initial heating they disappear following subsequent treatments at no greater duration and temperature. Warren[30] himself admits that a fever with a duration of only 20 per cent of the thermal death time will often cure a patient who is in good physical condition, especially patients with acute infections.

Combined systemic and additional local heating for the treatment of gonorrhea in the female was devised by Bierman and Horowitz.[4] They first elevate the temperature by physical means and then apply additional heating to the pelvic organs by diathermy. The average number of treatments for the eradication of all gonococci in a series of 121 cases was 1.4 per patient. (See Chapter on gynecological conditions.)

Gonorrheal complications such as epididymitis, prostatitis, seminal vesiculitis, pelvic cellulitis, cervicitis, salpingitis and gonococcic ophthalmia showed similar satisfactory response.

Gonorrheal arthritis according to unanimous reports receives almost dramatic relief from fever treatment. Eighty-eight per cent of the patients with acute gonococcic arthritis were promptly cured according to Hench *et al.*;[15] these results are striking and apparently superior to those obtained by other methods.

The advent of sulfanilamide and its derivatives for the treatment of infections brought about a considerable decrease in the demand for fever therapy as the first line of attack on gonorrhea. However, it soon developed that there were cases which failed to respond to chemical treatment, whereas they promptly yielded to combined fever and chemical therapy. A combination treatment has been worked out with the following routine: sulfathiazole 2 gm. is given at 12 noon the day before fever, repeated at 2 P.M., 6 P.M. and 10 P.M. the same day and at 2 A.M. and 6 A.M. on the next day. The fever treatment of eight hours at 106° F. is started at 8 A.M. that day. No other medication is given. Favorable results of such combination treatment were reported by Phillips and Mundorff,[24] King *et al.*,[16] Bundesen *et al.*[6]

Syphilis.—Carpenter, Boak and Warren[7] established the death time of treponemas in the laboratory at 41° C. (105.8° F.) as one hour and cured rabbit syphilis in several sessions of temperatures between 41° and 42° C. lasting six hours. Clinical studies in humans with early syphilis by Simpson[27] and others, with fever between 105° and 106° F., for fifty hours led to the prompt healing of the clinical lesions in some cases, but not to a reversal of the positive serological findings; furthermore, there was a relapse in a few cases. It was therefore concluded that while sustained fever will quickly kill the vast majority of spirochetes and quickly heal all skin lesions, it will not affect the more resistant germs in the lymph glands, and these serve as foci of reinfection.

Evidence presented by Simpson points to the fact that fever treatment combined with chemotherapy (arsphenamine and bismuth) will considerably reduce the average length of treatment and that in patients resistant to chemotherapy its combination with fever therapy is distinctly advantageous. Bundesen *et al*[6] report favorable results in early syphilis by the following fever chemotherapy routine: eight hours of fever at 106° (rectal) in the air-conditioned cabinet, first dose of mapharsen when the temperature reaches 100°, a second and third dose at the beginning of the third and fifth hour of maintained fever.

Neurosyphilis and Wassermann-Fast Syphilis.—In symptomatic neurosyphilis, asymptomatic neurosyphilis, ocular syphilis and resistant seropositive syphilis the results with fever therapy are at least comparable, if not superior to the results obtained with the more hazardous, time-consuming and inconstant malaria therapy (Simpson). O'Leary[22] states: "Spirochæta pallida has a high thermal death point (114° F.) so it would appear that the favorable results obtained in neurosyphilis by fever therapy whatever the type may be, are the result of some biological phenomena, the nature of which at present is not known." For further details see Chapter on affections of central nervous system.

Chorea.—In the majority of cases reported on there were excellent immediate results in the choreic movements of patients, with recovery in the majority of cases. Complicating rheumatic carditis showed striking response. For details see also Chapter XXVII.

Bronchial Asthma.—Encouraging reports by Philipps and others, justify fever therapy in cases of intractable bronchial asthma which fail to respond to other treatment. Mild degrees of fever should be employed.

Chronic Arthritis.—Reports in this condition vary chiefly on account of the variety of types treated and the difference in the method and scale of fever. There seems to be enough evidence to point to the value of mild fever therapy in infectious cases of arthritis. Good results were also reported in painful neuritic and radicular affections. For details see Chapter on chronic arthritis.

Multiple Sclerosis.—Fever therapy may result in temporary remission, but in advanced cases has no value.

Other Conditions.—Reports are on record on the favorable effect of fever therapy in rheumatic fever, undulant fever, lymphogranuloma venereum, meningococcus meningitis, corneal ulcers and iritis and a variety of chronic skin conditions.

CONTRAINDICATIONS TO HYPERTHERMY

To subject a patient to an artificial fever of from 105° to 106° F., sustained for five hours or more, is to subject him to a fairly strenuous cardiovascular functional test, according to the Council on Physical Therapy.[8] Patients with normal heart, kidneys and blood-vessels tolerate it well, but patients with myocardial degeneration or with valvular, coronary or other cardiac abnormalities, with impaired renal function from organic disease, with excessively high blood-pressure or arteriosclerosis, or with tuberculosis, diabetes or far advanced syphilis of the central nervous system (late, rapidly progressing neglected cases, or patients who are totally demented) do not tolerate such treatment well and should not be subjected to it.

Additional contraindications listed by Warren[31] are chronic alcoholism, acute respiratory infections and those rendered susceptible to heat prostration by a low salt intake during summer months. Mild valvular damage with full compensation is not necessarily a contraindication in patients under thirty years of age.

The age limit for administering fever treatments is about sixty years. Children of an age of two years have been successfully treated.

GENERAL TECHNIQUE OF HYPERTHERMY

Preparation.—A patient for fever treatment must undergo a thorough physical examination which should include a complete blood count and a twenty-four-hour specimen of urine. Any serious cardiorenal condition must be excluded and in doubtful cases an electrocardiogram, a roentgenogram of the chest and a chemical examination of the blood and that of the total sodium chloride in the urine should be made. If the fasting sugar level is low, a glucose tolerance test is advisable to determine the possibility of a pending hypoglycemic shock. The patient should have an ample bowel movement the day before the treatment; if not, the large bowel should be evacuated the night before by an enema or colonic irrigation. If a laxative or cathartic is to be given, this must be done early so that its results subside before treatment begins. Patients are encouraged to drink large amounts of fluids the day before treatment.

A preliminary conditioning session is advocated by Krusen[19] for all cases which are to receive a fever treatment of six hours or longer. It is given the afternoon before and consists of an erythemal dose of ultraviolet radiation, followed by immersion in a tub of hot water at 105° to 108° F. for half an hour, and wrapping the patient loosely in blankets for another hour and a half; all this in an effort to make the patient more tolerant to the long fever treatment. Krusen also states that on the morning of the treatment, 500 cc. of 5 per cent dextrose in physiologic saline solution may be injected intravenously.

Treatment is started about 8 or 9 A.M. and patients may arrive at the hospital just before that time or be admitted the night previously. Only a fluid breakfast should be taken. Patients are weighed and their temperature, pulse and respiration recorded as they are placed in the apparatus. A quiet, slightly darkened room is preferable and friends and relatives should not be allowed to visit. The specially trained nurse should give her full attention to the patient and the physician in charge should frequently visit and encourage the patient especially during the period of fever induction.

Knowledge of the medical supervision and nursing care of fever therapy can be acquired only under competent instruction with actual cases. The details of manipulation of controls of various types of fever apparatus can be explained by their manufacturers, but this is only the preliminary to an adequate clinical experience. Only the essential steps for the principal types of apparatus will be discussed here.

Initial Steps.—1. Inductothermy or coil field method. The single loop of the cable is permanently fixed to the framework, which supports the latex mattress which is covered with terry cloth to absorb perspiration. Before placing the patient in the cabinet it should be preheated to 110° F. by the resistance heater; during this time the head opening should be closed with a pillow. After the preheating the completely undressed patient is placed in the cabinet and the short-wave apparatus is turned on, with its full output properly tuned, while the cabinet temperature is maintained at 110°.

2. Condenser field method. If short-wave diathermy is applied in a fever cabinet this must be preheated as before. The nude patient is placed in the cabinet and the two condenser plates are suitably adjusted over his chest and abdomen. The full output is turned on and the patient is instructed to report any "hot spots" or any other unpleasant skin sensation at once.

3. Air-conditioned cabinets. The fever cabinet is preheated to 130° F. After the patient enters his body is covered with a thin linen sheet or terry cloth. After the desired temperature has been reached, the cabinet temperature is lowered to 110° to 115° F.

There are two steps in the production of artificial fever by physical means. One is the elevation of temperature to the desired level, also known as the induction period of fever, and the other is the maintenance of the fever level. The induction period is the most trying part for both patient and nurse.

The Induction Period.—After the patient has been placed in the apparatus and the controls for the administration of heat energy set, his temperature, pulse and respiration are recorded every fifteen to twenty minutes and any sudden changes are immediately reported to the physician in charge. The rise of temperature does not take place evenly in patients. Some have a tendency to a rapid rise, in others or in the same patients at different times the rise may take place more slowly. It is safer to cause a rise of not more than 1° F. every twenty minutes. In all events the rise of temperature to an average of 106° F. should take at least ninety minutes in all methods.

In all apparatus it is advisable to discontinue the electric energy when one degree below the desired height of temperature has been reached, because in most well-insulated patients the temperature keeps on rising after the heat-regulating mechanism of the body has been overcome. The temperature should never go above 107° F. and at the first session stay well below that height. In cases where there is doubt as to how the patient will stand the treatment a trial treatment of shorter duration and less fever may be planned.

Temperature measuring is done in the rectum and in the majority of cases an ordinary clinical rectal thermometer suffices. With all forms of high-frequency heating, the apparatus must be turned off when the rectal temperature is taken, otherwise the heating of the mercury will lead to false readings. In purely air-conditioned and luminous heat cabinets it is possible to use indicating electric thermometers, with their thermocouple ending left constantly in the rectum. These devices are expensive, but are labor savers and give immediate warning if the temperature should have a tendency to "overshoot." An instrument for the continuous recording of rectal temperature is available. (Fig. 189.)

The pulse is counted over the temporal artery. A rise of pulse-rate over 160 is a danger signal and if it remains at this level for one hour, treatment must be discontinued. If there is any question of cardio-circulatory disturbance the blood-pressure must be taken at intervals. Dropping of the systolic-pressure below 80 mm. of mercury and a pulse-pressure below 30 mm. of mercury calls also for immediate discontinuance of treatment.

Fig. 189.—Continuous recording rectal thermometer.

As the temperature of the patient keeps on rising, patients begin to perspire and a number of them show a period of mild *excitement,* especially while the fever rises from 102° to 104° F. It depends entirely on the mental make-up of the patient how troublesome this period is. Most of those of a determined type used to self discipline will go through this period under encouragement by the nurse and physician, with only a frequently changed cold moist compress over the forehead and a few cold drinks. Many patients will require a sedative. Finally there are very occasional patients who want to get out of the cabinet or their wrappings or women who become hysterical and in whom treatment cannot be kept up.

The *administration* of *sedatives* during fever treatment has received careful study. It has been established that the effect of sedative drugs during hyperpyrexia is greatly enhanced and there is also a probable effect on the heat center as well as a depression of the respiratory center. Hence only small and single doses of sedatives may be given safely. In the average patient a small dose of amytal (3 grains) or $1\frac{1}{2}$ grains of pentobarbital sodium given just before treatment or at the beginning of the restless period is helpful and well tolerated. In others the hypodermic administration of $\frac{1}{4}$ grain of morphine or $\frac{1}{3}$ grain of pantopon is more effective. It is not advisable to repeat this dose in case of continued restlessness.

The *administration of fluids* during the entire treatment is of vital importance. Patients not only get great comfort from repeated drinks from an iced solution of physiological salt solution, lemonade, orange juice, carbonated beverages, or sweetened tea, but proper fluid intake is also essential for the prevention of heat prostration and the more rapid restoration of the acid-base balance of the blood. During an average six to ten hours treatment, the patient should take 3 to 6 liters of a 0.3 or 0.6 per cent sodium chloride solution. Drinking of large quantities at one time should be discouraged because it may lead to nausea. The average temperature of fluids should be from 50° to 60° F. so as not to interfere with the maintenance of the fever.

Period of Maintenance.—During this period the technician must exert continued watchfulness to prevent unnecessary heat loss from the body. Such loss may be caused by frequent opening of the side doors of the cabinet, by passing into it cold urinals or bedpans, by prolonged cold packs on the neck, by large amounts of cold fluids ingested. During fever treatment some patients may not have normal bladder sensibility and the urge to urinate may not be manifest. A vague aching distress in the lower abdomen is usually due to a distended bladder.

At the height of fever temperature many well managed patients doze off and keep on sleeping during the entire maintenance period. This period may be extended from three to seven hours, according to the condition treated and the patient's tolerance. More than six hours of continued fever, especially around 106° F. entails a serious strain on the vasomotor system and requires great care. The fever maintenance is accomplished according to the method administered; with patients in well insulated fever cabinets the temperature usually stays up with the proper setting; if the temperature shows a tendency to drop, the heat-producing energy must be turned on again for an appropriate period.

End of Treatment.—After completion of the treatment time, the patient is taken out of the insulation or the cabinet, comfortably placed in bed, and his temperature will gradually drop to normal. According to the available facilities in some hospitals, patients are kept resting in the physical therapy department until their temperature has become normal, in others they are sent to their hospital beds. One must be careful not to expose the patient or allow him to become chilled at this period. When the temperature nears normal an alcohol rub may be administered. After a long fever session, patients must be restrained from food for a few hours, and their temperature should be observed for the next twelve hours. Patients upon reaching their bed usually fall asleep and wake up next morning somewhat fatigued. After shorter three- to four-hour fever sessions most patients feel quite normal and can be kept in bed often only with difficulty.

Height, Duration and Frequency of Fever Sessions.—With efficient physical methods it is possible to produce temperature elevations of a height only limited by considerations of safety and maintain them at this level for many hours. The rate and limit of rise depend on the amount of heating energy introduced, on the mass of the patient and on the efficiency of insulation.

Clinical experience during the past few years has developed two ranges of therapeutic fever, mild and severe. *Mild fevers* from 103° to 105° F. are maintained for three to six hours and may be employed in syphilis and its various sequelæ, in chorea, multiple sclerosis and other diseases, as well as in selected forms of arthritis and rheumatoid conditions. *Severe fevers* from 105° to 107° F. are maintained from five to seven hours or longer and are chiefly employed in gonorrhea and its complications. The longest fever maintenance reported by Warren was twenty-seven hours.

The following table is being employed at the New York Polyclinic Hospital for the information of physicians interested in the routine of fever therapy.

TABLE 29.—REFERENCE TABLE FOR HYPERTHERMY TREATMENTS

	Treatments			
Disease	Number	Frequency	Height	Duration, hours
Gonorrheal complications (including arthritis)	4 to 6	2 x week	105 to 107	5 to 6
Neurosyphilis	6 to 10	1 x week		
Ocular syphilis	...	2 x week	105	5
Arthritis (rheumatoid)	6 to 10	1 x week	103	3 to 5

COMPLICATIONS OF HYPERTHERMY

Restlessness.—Restlessness is the most frequent reaction in fever patients and can usually be quite well controlled by the means described previously. In psychiatric patients with an anxious, unstable personality, delirious episodes are frequently apt to occur; according to Ebaugh, Barnacle and Ewalt[12] such patients should be accepted only if they respond to psychotherapeutic measures, for it is well known that paretics do not tolerate the administration of sedatives. Gonorrhœic patients seem to require sedatives more often than any other group. Alcoholics are most difficult to manage.

Heat Prostration.—Heat prostration may be evidenced by an uncontrollable restlessness, or increasing exhaustion or the symptoms of tetany. Keeping of a sufficient intake of fluid and sodium chloride are best preventatives. In addition cold compresses or the playing of a fan over the face help to keep the patient comfortable. Warren advises excluding patients rendered susceptible to heat prostration by a low salt intake during the summer months or by acute respiratory infections.

Burns.—Burns occur not infrequently in fever treatments even with the most careful technique. However, in the great majority of cases they consist only of small blisters over especially heat sensitive parts of the skin. These minor burns heal without scarring and do not necessitate discontinuance of further treatment. With diathermy plates and short-wave pads, burns may be caused by undue density of current in areas too close to the electrodes or those rendered anemic by pressure. They may become severe if the patient is not warned to report any localized feeling of excess heat at once. In fever cabinets contact with a heating element or light bulb can occur only in extremely restless and uncontrolled patients. However, the superheated air can and does sometimes cause very extensive blistering and subsequent scar formation. For this reason, in all fever treatments with high temperatures and, especially, in light haired thin skinned patients, the skin must be watched most carefully for signs of undue reddening as a precursor of a burn. Such areas may be cooled by rubbing with ice and also protected with extra padding. Bony prominences, scars, pendulous breasts and the skin of the toes are especially vulnerable.

Herpes Labialis.—Herpes labialis occurs in a fair percentage of cases, three or four days after the first treatment. Occurrence of herpes of the cornea in one case was reported and was also seen in one case of the author's after the second treatment. Both of these lesions cleared up without complications and there is no way at present to prevent this rare occurrence. Warren[31] *et al.* found that out of 411 fever therapy patients, 190—almost every other one—developed herpes, but only 7 of 131 in subsequent treatments, suggesting that some immunity develops after the first attack. Neither the method of fever production or the height or duration of fever bear direct relation to the occurrence of herpes, which usually clears up spontaneously.

Heat Cramps and Tetany.—Tetany is a rather rare occurrence, manifesting itself by twitching of the arms and legs and at times the abdominal wall. It is attributed to alkalosis caused by hyperventilation and it may occur whenever the temperature rise occurs very rapidly, as for instance in hot-water baths; but it may occur also in cabinets for the same reason. The symptoms may be promptly relieved by the intramuscular or intravenous injection of 10 per cent calcium gluconate.

Abdominal cramps, nausea and vomiting are other rare occurrences chiefly reported with the use of fever cabinets. Minor instances may occur in patients who have eaten too much breakfast contrary to advice. Excessive nausea may necessitate the termination of treatment because it not only weakens the patient but also prevents his drinking of salt solution. Desjardins[10] states that an intravenous injection of 500 to 1000 cc. of a solution containing 10 per cent of dextrose and 1 per cent of sodium chloride rapidly relieves this condition. Rosenberg and Epstein[25] advocate the routine administration of hypertonic (5 per cent) saline solution immediately preceding fever therapy to reduce the incidence, frequency and severity of nausea and vomiting and also to reduce the incidence and severity of reactions to intolerance to heat and postoperative debility.

Circulatory Collapse.—Vasomotor collapse is a rare complication and is characterized by a gradual or sudden increase of pulse-rate with cyanosis. To avoid this serious complication, whenever the pulse exceeds 160 for any length of time and is of poor quality, treatment must be stopped. Inhalation of oxygen with 7 per cent concentration of CO_2 is at once employed as well as intravenous infusion of normal saline and 5 per cent glucose, 800 to 1500 cc., to give the heart fluid to pump. In addition, caffein, sodium benzoate and adrenalin may be injected. Sedatives should not be used unless to control convulsions. Cullen *et al.*[9] have found that oxygen therapy prevents reduction in arterial oxygen tension and thus should be used during fever therapy.

Sudden, uncontrolled hyperpyrexia, associated with circulatory collapse and followed by deep coma is the rarest accident in the experience of Stecher and Solomon.[28] Sudden rise of temperature may occur in both mild and severe treatments. Its management consists of removing the patient immediately from the cabinet or his wrappings, directing an electric fan against his body and administering adrenalin intramuscularly if indicated. Gentle rubbing of the extremities with cooled water (50° to 60° F. is recommended) (Schmitt[26]) to increase the rate of evaporation from the skin; if the temperature keeps on rising or is only slightly dropped, the trunk should be cooled with the exception of the abdomen. The rate of temperature reduction however should not be too rapid, after a drop of 3° or 4° the body should be lightly covered and the temperature further observed; a second treatment may be administered within an hour if no further decline occurs.

Pathogenesis of Fatal Cases.—The mortality in well administered fever treatments is small. The pathological changes as seen by Hartman and Major[14] in patients and experimental animals following artificial fever therapy consisted of marked engorgement of the blood-vessels, especially of the capillaries, associated with hemorrhage of varying extent and necrosis of the tissues, including the muscles, liver, kidney, lungs, adrenals and brain. The hemorrhages and patchy necrosis in the central nervous system are a striking and consistent finding, especially where the sedative used is a respiratory depressant, as morphine, pantopon or one of the barbiturates.

According to Hartman[13] untoward results of fever therapy are always preceded by cyanosis and vascular collapse. He considers anoxia as the underlying cause of the lesions described and the sedatives administered as its initiating or predisposing cause. Anoxia may be prevented by the administration of oxygen throughout fever therapy, provided respiration and blood-pressure are maintained at reasonable levels.

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CHAPTER XIII

ELECTROSURGERY

General Considerations. History. Electrosurgical Methods. Apparatus. Technique of Electrodesiccation. Technique of Electrocoagulation. Technique of Electrosurgical Cutting. Anesthesia in Electrosurgery. Clinical Uses. Critique.

General Considerations.—Electrosurgery or surgical diathermy denotes the application of electricity for the destruction of new growths and diseased tissue and for cutting through normal tissues with minimal bleeding. In the strict sense of the term the electrocautery (the employment of metal tips or wires heated by the lighting current) and electrolysis for the removal of superfluous hair and for destruction of tissue would also come under the heading of electrosurgery. Modern usage has, however, restricted the term of electrosurgery to the surgical application of high-frequency electrical currents.

The principle of action of all electrosurgical methods is an intense concentration of current under a small active electrode; this results in a destructive heat effect which leads to instantaneous coagulation of the albumin of the tissues. The extent and form of tissue destruction varies with the type of current and the technique of application. Heated metals in the form of the electrocautery have been used for a long time for the destruction of superficial tissues and malignancies but their action is superficial and the heat cannot be maintained at an even temperature; if they are too hot, normal as well as malignant tissue is destroyed. With high-frequency electrosurgical apparatus the scalpel or needle remains cold all through the operation, the heat generated is in the tissues themselves and is always under perfect control of the operator.

History.—Oudin was the first to describe, in 1899, the tissue-destroying effects of sparks derived from a resonator attached to the d'Arsonval solenoid. Rivière, in 1900, advocated them in the form of an "effleuve" for malignant tumors and tuberculous skin lesions. Subsequently, deKeating Hart and Doyen published results on cancer treated with powerful sparks drawn from a high-tension transformer. They used a biterminal technique, producing heavy carbonization of tissues and named the method "fulguration." In the United States, F. R. Cook first described, in 1907, the use of high-frequency sparks for the destruction of abnormal tissue, and Beer employed it for tumors of the bladder. In 1909, Clark, of Philadelphia, developed the technique of electrodesiccation, or the drying of tissue without actual coagulation. He made studies subsequently of the biterminal, more penetrating method of electrocoagulation and rendered a classical description of the histopathological effect of these two procedures. In the past decades Wyeth,[21] Cushing,[3] Kelly and Ward,[12] and others developed these methods further.

Electrosurgical methods have come to fill a very definite rôle in both major and minor surgery. When first introduced in the form of desiccation and coagulation they were welcomed for their effectiveness in local tissue destruction. From the original field of tumor surgery the newer method of electrical cutting and its modifications have brought electrosurgery into the field of general surgery, enabling the successful attack on vascular organs anywhere in the body and leading to a new surgical technique.

ELECTROSURGICAL METHODS AND THEIR EFFECTS

The three major varieties of electrosurgical effects are shown in Table 30.

TABLE 30.—ELECTROSURGICAL METHODS

Form		Technique	Characteristic effects
Electrodesiccation	Monoterminal	Needle-point single electrode connected to high voltage (Oudin) terminal and held in contact or at slight distance	Dehydration and shrinkage of superficial parts
Electrocoagulation	BITERMINAL	Operating (active) needle or ball point electrode connected to one terminal, large dispersive electrode to the other	Coagulation of cell protoplasm; sealing of small blood-vessels by active electrode
		Biterminal needle electrode or clamp connected to two terminals	Coagulation limited to area between biactive points
Electrosection or electric cutting		Operating electrode a needle point or blade connected to one terminal; dispersive electrode to other terminal	Dissection of tissues with a minimum of coagulation; sealing of capillaries only

Electrodesiccation.—A needle-point electrode is connected to the single high-voltage (Oudin) terminal of the long-wave diathermy apparatus and held in contact with or at a slight sparking distance to the area to be treated. The current employed is one of comparatively high voltage and low amperage and its oscillations are damped. When this current is applied to the tissues at appropriate strength and duration, drying and shrinkage of the parts occur, due to the evaporation of the water content of the cells. A dry mass remains which can be curetted away or left in place to slough off in due time.

Histological Changes.—Following electrodesiccation, Clark showed tissue cells shrunken and shriveled, their nuclei condensed and elongated, with a suggestion of cell outline, the whole assuming a mummified appearance (mummification necrosis). The blood-vessels were thrombosed and there were no evidences of hemorrhage. Since this mode of cell death is associated with very little degenerative change and scant disintegrated material, there is but a small amount of fibrous tissue as an end-result. This explains the good cosmetic results and the fact that the neighboring healthy tissues are spared the devitalization resulting from the formation of abundant contractile fibrous tissue.

Electrocoagulation.—The current employed in electrocoagulation is one of higher amperage and of damped oscillations. There exist two techniques in electrocoagulation: (1) The usual method is to connect an "active" needle or other pointed electrode to one terminal of a high-frequency apparatus and a large dispersing one to the other terminal. Wherever the active electrode is brought in contact with the tissues, a grayish white

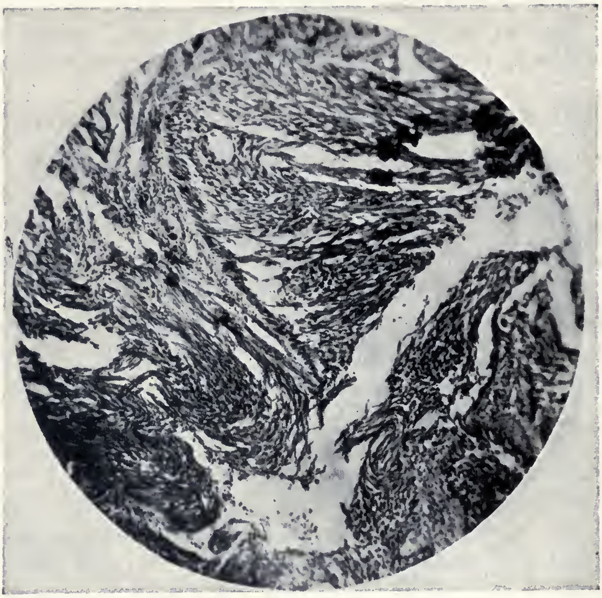

Fig. 190.—Photomicrograph showing desiccation with Oudin current. (Dr. G. E. Ward.) Tumor cells are dehydrated, elongated and shriveled with shrunken nuclei. (Courtesy of Journal of the American Medical Association and W. B. Saunders Company.)

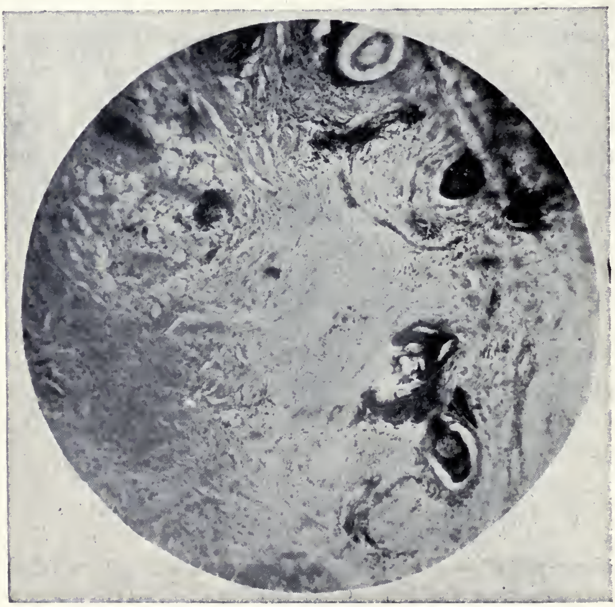

Fig. 191.—Photomicrograph showing coagulation with biterminal damped current. (Dr. G. E. Ward.) Tumor cells have been changed into masses of homogeneous débris by the high temperature which literally boils them in their own tissue juice. Blood-vessels are clotted and the stroma is converted into a hyaline mass with sparsely scattered nuclei. (Courtesy of Journal of the American Medical Association and W. B. Saunders Company.)

discoloration of varying depth appears, corresponding with widespread coagulation of these tissues. (2) A modified method of electrocoagulation consists of the employment of two active electrodes, two needle-points or a specially constructed clamp electrode. This is called *biterminal coagulation.* As a result of this technique, coagulation only occurs in the small area between the two active electrodes.

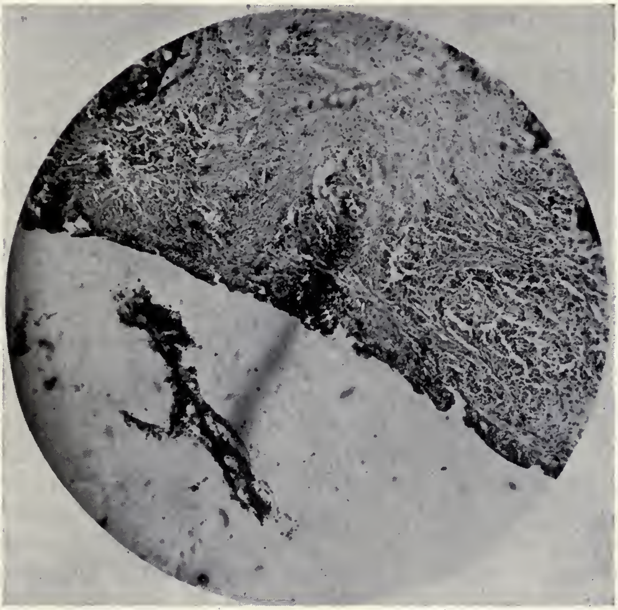

Fig. 192.—Photomicrograph of incision made with cutting current from tube apparatus, showing fine line destruction 10 μ in thickness or less. (Dr. G. E. Ward.) Primary union is the rule here. (Courtesy of W. B. Saunders Company.)

Histological Change.—Following electrocoagulation Clark showed histologically that the cell outline is entirely lost; the affected tissue elements become fused into a structureless homogeneous mass presenting an appearance not unlike that of hyalinization. This greater degree of destruction results finally in a proportionally greater amount of fibrous tissue (scar) formation. Investigations by Keysser[13] and Nieden[19] show two definite zones in the coagulated area. The inner zone is blanched and on histological examination shows typical coagulation necrosis in which the tissues are shrunken; the nuclei have lost their definition, stain poorly or disappear altogether. This inner zone shows a primary heat effect identical with the necrosis of ordinary skin burns. It passes over into an ill-defined zone of shriveled cells and a region of dilated blood-vessels. Examinations made several days later show that the outer zone becomes invaded by round-cell infiltration, fibroblasts and foreign-body giant-cell formation. Nieden pointed out that deep coagulation even in the inner zone of complete necrosis is always uneven according to the variation of resistance in different tissues and the resulting tissue injury is, therefore, unpredictable. Unexpected coagulation necrosis accounts for the dangerous secondary hemorrhages occurring after electrocoagulation in the neighborhood of large blood-vessels. For this reason there appears to be a tendency in electrosurgery to get away from massive coagulation as being unsurgical and dangerous and lean toward the use of cutting currents.

Electrosection.—A needle-point or thin blade is connected to one terminal of an apparatus producing a current of undamped oscillations; a large dispersive electrode is connected to the other terminal. With appropriate strength of current, the active or operating electrode applied to the tissues will glide through them with ease. Like butter under a hot knife, the tissues almost melt under the influence of the cutting current. The *histological effect* also occurs in two zones. The innermost area is a zone of molecular disruption due to the explosion of cells. There is no clear-cut explanation of this process as yet. One explanation is that the assumption by the molecules in the tissues of a high rate of vibration causes dissolution of the molecular structure; another explanation is that the sudden expansion of the cell, due to intensive heating, converts its liquid contents into explosive steam. In the outer zone there is evidence of elongation of tissue cells and a slight amount of coagulation. The width of these zones equals about 0.1 mm. when the average cutting strength is employed.

The high frequency resistance of the various tissues, as shown in Table 26, accounts for a certain variation of resistance to electrical cutting. There is much more resistance when cutting through fat than through skin and muscle, hence more power must be used.

Healing of Electrosurgical Wounds.—A study by Ellis[5] on the healing of electrosurgical wounds in different tissues after coagulation and cutting showed that it is not possible to produce a purely cutting effect without some necrosis on a skin with a horny layer, but this slight necrosis does not always preclude healing by primary intention. In comparison with 97.5 per cent of primary union in scalpel wounds, Ellis found 60 per cent primary union in electrosurgically produced wounds. In the mid-period of healing the electric wounds are weaker, as shown in animal experiments by comparison of the tensile strength in the wounds. The healing of wounds by the cutting current in skeletal muscles and the muscular wall of the stomach and intestines have been found entirely comparable in strength to scalpel wounds and without secondary necrosis or infection. The coagulation current causes in skeletal muscles and in hollow organs the same inverted coagulation as in the skin and healing occurs after absorption of the necrotic area by extensive fibrosis.

Specific Effects on Blood-vessels.—The most important argument in favor of electrosurgery is the effect on the three classes of blood-vessels.

1. Very small vessels, capillaries, arterioles and venules. These are vessels of a size which do not usually bleed after a clamp is removed during operation. When tissues containing such vessels are severed with a cutting current without any zone of coagulation, there is momentarily some capillary hemorrhage but within a few minutes this hemorrhage ceases completely. In organs with oozing capillary beds, such as the liver, spleen, brain, the kidney, and in muscles, this result offers a revelation to most surgeons. Investigation by Heitz-Boyer[9] showed histologically obstruction of the lumen by endothelial lining cells and wrinkling of the vessel wall and in laboratory tests an abundant liberation of thrombokinase from the vascular wall. The latter phenomenon accounts for the sudden and effective hemostasis by the cutting current. A flash, a simple division of the tissue by the cutting current is sufficient to produce the sealing effect.

2. Small or moderate-size vessels, which bleed after taking the clamp off and must be ligated in ordinary surgery. These vessels are usually not obliterated by the cutting current but can be successfully sealed off by the coagulating current. The usual method of accomplishing this is to touch either the hemostat which grips them or touch the vessel directly by the tip of the coagulating electrode. The less tissue coagulated the less necrosis follows and the less the chance of secondary hemorrhage or infection from the thrombosed blood-vessel.

3. Larger blood-vessels, of the size of the radial artery or larger. In these Ellis[6] found merely the occurrence of a coagulation thrombosis in the vessel; the vessel wall was not destroyed. In these vessels the customary ligation is preferable to electrical hemotasis.

In experimental work with nephrotomy Higgins and Glazier[10] found that there is less primary hemorrhage when an extensive nephrotomy is performed with the cutting current than with the scalpel.

Advantages of Electrosurgery.—On the basis of the changes described the advantages claimed for electrosurgery are:

1. Lessening or elimination of bleeding; the immediate sealing of blood-vessels and lymph vessels gives not only a clearer and better operating field but also sterilizes it to a great extent.

2. Facilitating the rapid and gentle handling of even the most delicate tissues, enabling the use of fewer and simpler instruments and the wider use of local anesthesia and brief gas anesthesia.

3. Lessening of operative shock and after pain for reasons already stated and also through decrease of the capillary wound surface, through slowing up the resorption of toxic tissue products and by destruction of afferent nerve paths of pain.

4. Promoting more rapid healing in the average case in comparison with wounds left to granulate after ordinary surgery, promoting an antiseptic after course and leading to a softer and less disfiguring scar; at the same time follow-up work in overlooked or recurrent areas is much easier.

APPARATUS FOR ELECTROSURGERY

The two types of high-frequency apparatus serving for electrosurgery are the spark-gap type, producing damped oscillations, and the tube type producing undamped oscillations.

Spark-gap apparatus produces principally a current suitable for fine desiccation and heavy coagulation but not for electrosection; with suitable modification—superimposing trains of damped oscillations which produce an equivalent of an undamped current—it has been used for cutting purposes. The modern short-wave diathermy tube apparatus is eminently suited for cutting and light coagulation. The physics and control of the two types of apparatus have been described in Chapter X.

The so-called blended current is offered by a special electrosurgical unit containing both a spark-gap and a tube circuit. This arrangement enables the combination of the tissue cutting effect of the vacuum tube apparatus with the coagulating effects of the spark-gap current (Fig. 193). An additional simplification of controls serves for rapid adjustment of currents and thus the blended current apparatus enables a more efficient electrosurgical control and combination of all effects.

Additional *equipment* needed for electrosurgery consists of the following: a needle for desiccation, preferably mounted on a handle with a make-

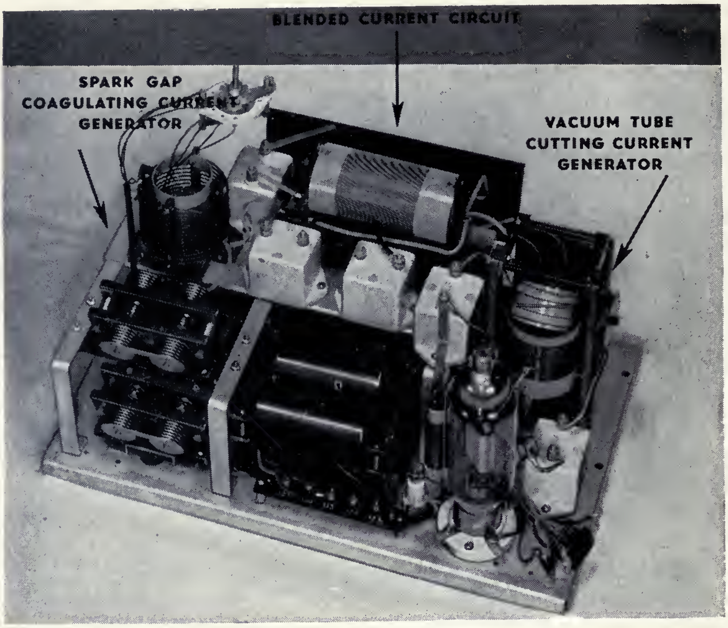

FIG. 193.—Interior of blended current producing apparatus. (Courtesy of the Burdick Corp.)

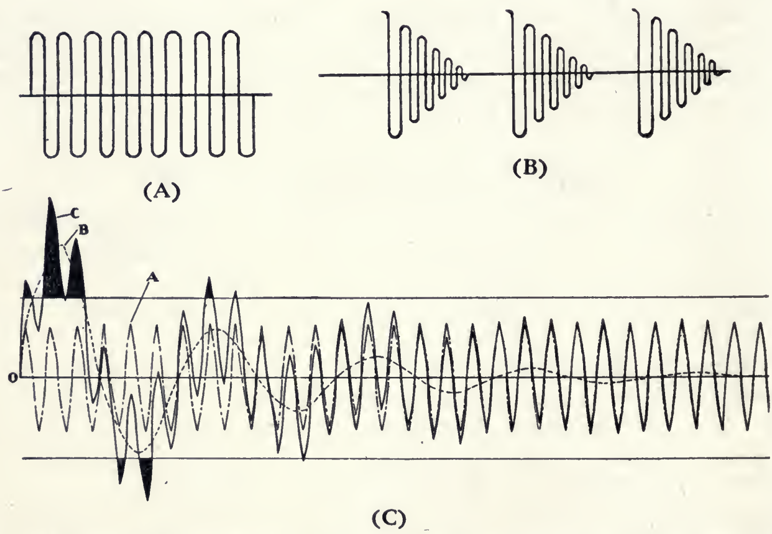

FIG. 194.—Diagram of undamped (*A*) and damped (*B*) high-frequency oscillations and their combination (*C*) ("blended" current for electrosurgery). (Courtesy of the Burdick Corporation.)

and-break arrangement; two sizes of ball electrodes for coagulation; straight and curved flat blades for cutting and loops for scalloping out unresectable areas; also biterminal electrodes. Some of these electrodes are illustrated in Figures 195 and 196. For gynecological, nose and throat and rectal work special electrodes serve. A foot switch is indispensable for quickly starting and stopping the power flow and keeping the operator's hands free. (Fig. 198.)

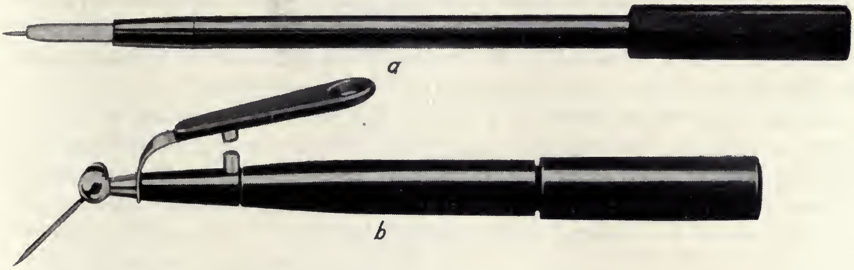

FIG. 195.—Electrodes for general electrosurgery: *a*, fine needle; *b*, heavy needle with make-and-break control on handle. (Courtesy of Wappler, Inc.)

The factors influencing the amount of tissue destruction in any electrosurgical procedure, whether desiccation, coagulation, or cutting with the plain tube or blended current are several: (1) The amount of power used—the more power, the more destruction. (2) The length of application—(*a*) longer contact, deeper desiccation or coagulation—(*b*) the faster the cutting electrode is moved, the less destruction on each side of the incision. (3) The size of the electrode also affects the tissue change—larger surface contact gives more room for current to flow and therefore produces more destruction.

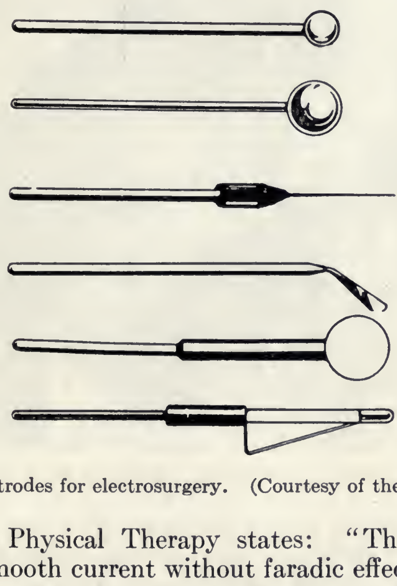

FIG. 196.—Special electrodes for electrosurgery. (Courtesy of the Burdick Corporation.)

The Council on Physical Therapy states: "The perfect generator should produce a smooth current without faradic effect, varying from the finest desiccation spark to heavy coagulation without much flashing or uncontrollable flame. Efficient coagulation by a blunt or ball electrode brought near to the tissues, with the minimal visible sparking, is another criterion of a perfect current. There ought not to be any fusion of coagulated tissues to the electrode but to date no material is available out of which electrodes can be made which will not stick to the tissues, pulling some away when removed and risking tearing a vessel. In addition, the cutting current should be adjustable from one, severing tissue with only 0.1 mm. of destruction on each side, to one, coagulating 1 or 2 mm. in depth. All these features, characterizing the perfect machine with the minimum number of controls, should be available at the operating table through a proper foot switch or by sterile connections for the operator's immediate control, without calling for an extra assistant."

A safe and efficient working knowledge of electrosurgical apparatus must be acquired by experimental practice on meat and on animals and later by actual work on patients, under the guidance of an experienced colleague. The principles and technique of the three main methods are only presented for general guidance.

TECHNIQUE OF ELECTRODESICCATION

In electrodesiccation only one electrode is employed, a steel or platinum needle of varying thickness, held in an insulating handle, with a make-and-break arrangement, or still better, with a foot switch. Proper control of current strength and duration of flow and the employment of a fine

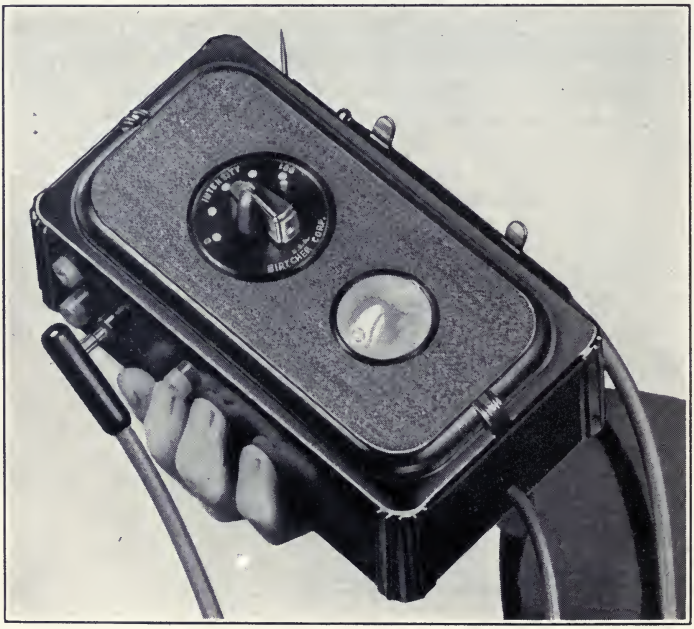

Fig. 197.—Small unit for electrodesiccation. (Courtesy of the Birtcher Corporation.)

desiccating needle should enable the operator to dry off small growths with very little pain, no hemorrhage and with very little subsequent scar tissue. Small growths on the cornea can be removed without impairment of vision by subsequent scar tissue and papillomas of the vocal cord without any impairment of phonation.

The physician must learn to produce a minimum sparking at first and increase current strength, if necessary, according to the size and consistency of the growth. Since there is no meter in circuit to measure the current strength, the operator must begin with a minimum spark and increase its intensity to adequate requirement.

Experimental Practice.—Insert the needle holder in the Oudin terminal. Start the current flow in the apparatus and open the rheostat slightly with the spark-gap closed. (If there is an extra control rod for the spark-gap it should be closed all the way in so that the current is short-circuited in the machine.) Approach with the needle a cylindrical metal electrode or any other metallic object held in the operator's hand. No sparking occurs until the spark-gap is slightly opened. Learn to produce a spark length of only about $\frac{1}{16}$ inch. This will cause no sensation whatsoever in the operator's hand on account of the diffusion of the current from the comparatively large metallic surface.

Next, learn to approach your own thumb nail with the desiccation needle, turning on just enough current to produce visible sparking through the nail. Such current strength is practically painless if kept up only for a fraction of time. The author invariably determines by this method the minimum current strength suitable to begin desiccation.

Clark's classical soap experiment should be practiced by all beginners to visualize how actual drying of tissues can be accomplished without carbonization, by a minimum of current. Cover a cake of white soap with one thickness of white paper. Bring the needle in direct contact with the paper and turn on just enough current to cause no trace on the paper, but to dry out the soap on the area immediately below, causing a minute erosion filled with dried-out soap. This is the current strength just sufficient for fine desiccation.

The final experiment should be done on a piece of meat—beef or liver, moist and warm, so as to approximate living tissue. Allow a fine stream of sparks to flow over it without actual contact and observe the drying out of the superficial layers. Note how the extent of destruction can be varied at various settings of the rheostat and spark-gap and with a varying size of the sparks from the very thinnest to large "hot" ones. Note that it takes less current and fewer sparks to dry out less vascular and less juicy tissue.

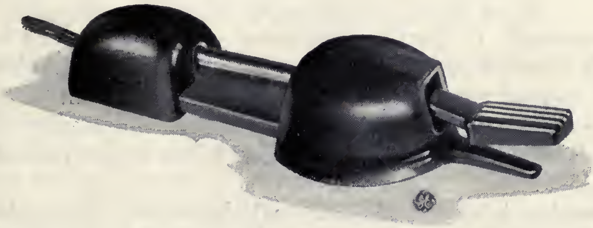

FIG. 198.—Foot switch for electrosurgical apparatus. (Courtesy of the General Electric *X*-ray Corporation.)

Operative Technique.—The part to be treated should rest on a non-conducting support preferably a wooden table. The operator should be seated and have good support of the arm holding the desiccating instrument. There should be good light and the controls of the apparatus should be within easy reach if one is working alone. The use of a separate foot switch is more convenient. In tonsil and rectal work it is often preferable to have an assistant present to take charge of the controls according to the instruction of the operator. The conducting cords should be heavily insulated in order to prevent unpleasant leakage of the current to the operator's hand.

After the current flow to the apparatus has been started (the main switch being closed), the controls are opened to the desired strength. The needle is held just far enough from the lesion to produce a minute spark. As soon as the current has flown at sufficient strength, a whitish discoloration appears, showing that the tissue has been dried out; the needle is then moved to the adjoining surface. The strength of the current is regulated according to the size and density of the growth or diseased area. The rule is to use as little amperage as possible and work more on the spark-gap control; this tends to keep down current volume and prevents excessive scar (keloid) formation. This technique is just contrary to the usual technique in diathermy where the rheostat control is advanced as far as necessary and the spark-gap control is kept down as much as possible.

Fig. 199.—Papilloma of the tongue before electrodesiccation. Courtesy of Dr. J. J. Eller.)

Fig. 200.—Papilloma of the tongue after electrodesiccation. (Courtesy of Dr. J. J. Eller.)

Current strength to destroy growths of varying size must be estimated. When the lesion is superficial the current is best delivered through a short air space; when of medium size the needle is brought in contact with the tissue to be destroyed; when the growth is large the needle is inserted into the tissue. The length of flow is the other factor in determining the extent of destruction.

The operation is ended when the whole growth turns white or when, the needle being placed in the lesion, the spark lights up like flame in the tissue, showing that the entire lesion has been dried out. A dry shrunken appearance of the treated area as if receding from the surrounding normal structures is also a sign of sufficient treatment. In case of doubt whether all pathological tissue has been destroyed, one should remember that it is easy to make up for insufficient dehydration at the time of the first or later follow-up examinations. Too extensive sparking may cause slow-healing ulceration.

Local anesthesia is usually not necessary when treating small skin lesions or cervical erosions; in cases of hemorrhoids or tonsils or more extended areas in other locations, local anesthesia is essential. Small pedunculated growths may be almost painlessly treated by the following technique: Grasp the base with fine forceps and apply the desiccating current to the top of the growth; the forceps grounds the surplus current through the operator and the growth shrivels up without any painful sensation and can be removed without bleeding.

At the end of the operation small growths and other pathological tissue may be left *in situ* to dry off and separate spontaneously. The sterile dry scab usually affords protection and insures better cosmetic result. Most of the growths, both small and large, are, however, best curetted off immediately. The raw area should be lightly sparked over to prevent oozing and infection and then may be painted over with 7 per cent iodine, mercurochrome or Bohlman's gentian violet solution (gentian violet, 2 grams; 95 per cent alcohol, 55 cc.; acetone, 10 cc.; distilled water 35 cc.). A small neat adhesive plaster dressing will further protect the area. Over areas of the face where a perfect cosmetic result is desired it is better to apply a bland ointment and a small gauze dressing, for this obviates injury to the sensitive epithelium when an adhesive plaster dressing is pulled off. A sterile dry dressing should be employed over any larger area of destruction.

Healing of dry scabs over small areas usually occurs within ten days. Pus may form under the scab. If there is any indication of it, the scab must be removed for drainage to insure undisturbed healing with good cosmetic result. Epithelialization may be further stimulated by a balsam of Peru or 5 per cent scarlet red ointment. Larger growths (up to 1 cm. in diameter) may require from one to three weeks for complete epithelialization. The resulting scar is usually smooth and pliable. Growths on mucous surfaces are best allowed to slough off spontaneously after desiccation; this avoids the possibility of secondary hemorrhage after curetting.

Patients should return for re-examination as after any other surgical procedure. Areas previously not entirely desiccated can be thus more thoroughly treated and subsequent new growths recognized early.

TECHNIQUE OF ELECTROCOAGULATION

Electrocoagulation serves for the destruction of larger new growths or larger amounts of diseased tissue. Conditions amenable to desiccation may be more thoroughly eradicated by coagulation. The difference between the two methods is often only of degree. Due to the variable factors in current control and in the electrical resistance of the tissues, fine desiccation may also be effected by mild biterminal application.

Electrodes.—For the active electrode in electrocoagulation, a needle or a small-sized ball attached to an insulated holder are employed. For electrohemostasis, the tip of a hemostat suffices.

A dispersive electrode is used in both electrocoagulation and cutting, in order to complete the electrical circuit through the body. It consists of a fairly large plate of diathermy metal, about 8 by 10 inches in size. It is best placed under the buttocks at a safe distance from the field of operation. It must be in good contact with the skin at all times and well insulated by sheet rubber from the operating table or other metal parts.

The dispersive electrode should be rolled perfectly flat before use each time so as to avoid poor or uneven contact due to surface irregularities. Sharp points may cause burns. It is advisable to securely fix the dispersing electrode by an elastic bandage so as to prevent its displacement if the patient moves. For light work the electrode may be bandaged to the arm or applied to the back of the neck and for these locations a smaller, 3 by 6, plate will suffice. Special caution must be taken to securely attach the conducting cord to the dispersing plate and to protect the skin against pressure or contact by the connecting clip.

The use of the term indifferent or inactive plate instead of dispersing plate should be avoided because it misleads beginners to believe that no action takes place beneath this electrode and, therefore, no attention has to be paid to it. As a matter of fact, severe burns have occurred under improperly applied dispersive plates and the victim of such an occurrence will hardly call the means of such an unpleasant effect an "indifferent" one.

Experimental Practice.—Preliminary experimental work on moist and warm dead tissue is essential: (1) To learn to estimate the coagulating power of the apparatus; (2) to observe the tissue changes under different settings, technique and also on a variety of tissues; and (3) to acquire the necessary dexterity in handling the electrodes and the controls of the apparatus.

Equipment.—Apparatus, two conducting cords, an active electrode such as steel needle in an insulated holder and a fairly large dispersive plate. Place a piece of juicy meat about 2 inches thick and about 5 by 5 inches in size preferably containing some fat, cartilage and fascia, on the dispersive plate.

1. Insert the active electrode to a depth of about ½ inch and turn on a fairly heavy current. In a few seconds gray blanching will appear all around the needle and hissing noise of escaping steam is heard. The coagulated tissue becomes drier and drier and finally sparking takes place from all sides of the coagulated area. This is the sign that the part is quite dry and no longer conducts the current. It is also the sign to discontinue the current immediately. Cutting through the coagulated tissue one finds a moderate amount of coagulation extending in all directions from the needle track. There is a well-marked line of demarcation between coagulated and unaffected tissue.

2. The same active electrode is similarly inserted into another part of the meat. Approximately only one-half of the current strength employed before is turned on and kept up considerably longer. Cutting through the coagulated area it will be noted that its extent is much greater and the line of demarcation between the coagulated part and the unaffected one is irregular and ill-defined.

These experiments demonstrate that the depth of destruction under the active electrode depends on the strength as well as on the duration of current flow and that a heavy current flowing for a short time does not coagulate so deeply as a lighter current flowing for a longer period. Rapid drying of the surrounding tissue causes loss of conductivity and sparking around the coagulated part.

3. Insert the active electrode successively into meat, fat and fascia and note the difference in the setting of the rheostat and spark-gap necessary

to produce coagulation to the same extent and during the same time. Continue these observations on live animals and on human tissues, preferably under the guidance of an experienced operator.

The Rôle of the Milliammeter.—There is no meter in circuit during electrodesiccation and most operators consider it unnecessary to employ a meter during electrocoagulation. It is not practicable to measure the current strength necessary for destruction by a meter, because it may vary from 300 to 3000 or more milliamperes. When a meter is used its reading is materially influenced by the resistance in the circuit. This, in turn, is determined by the size and density of the tissues, the size of the patient, the distance of the dispersive electrode and the size of the active electrode itself. Observation of the actual coagulation effected is a more practical guide in regulating the current strength.

The violent fluctuations of current strength during operation frequently lead to burning out of the meter. For the reasons given, most spark-gap apparatus provide a set of binding posts, marked "electrocoagulation," which permit drawing of the full amount of current without any meter in circuit.

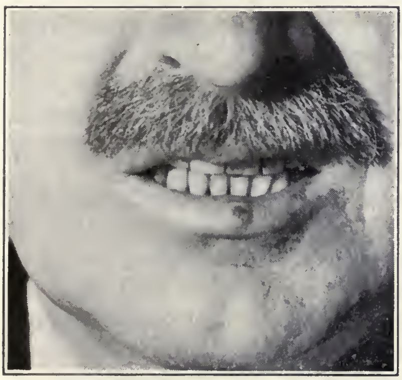

Fig. 201.—Epithelioma of the lower lip; duration, four and a half months. (Courtesy of Dr. J. J. Eller.)

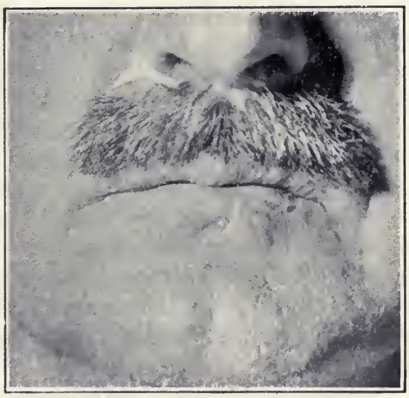

Fig. 202.—Same patient as shown in Figure 201 after electrocoagulation of epithelioma. (Courtesy of Dr. J. J. Eller.)

Operative Technique.—Patient must be prepared as for a major surgical operation. Local or general anesthesia is necessary, according to the size and location of the new growth. For light work on mucous membranes the topical use of novocaine or a drop of benzyl alcohol is usually satisfactory. In injecting a local anesthetic one should avoid infiltration of the operating field with a large quantity of fluid and rather inject around or under the operative area or employ nerve-blocking.

During operation conducting cords should not come in contact at any time and should not lie too near any metal part or to the patient and operator. A short-circuit, causing unpleasant shock, scorching and burning out of the milliammeter, may be the result on account of the heavy current flowing. Using sheet-rubber insulation liberally all over the field of operation is the best prevention of accidental short-circuiting.

In performing the operation, as soon as the current is started a grayish-white discoloration, indicating coagulation, occurs under the needle. The needle is moved in succession over the area to be destroyed. It is preferable not to lift it off in order not to break contact. As destruction to an increasing depth occurs, if the growth is vascular, the tissue fluids begin to boil; soon sparks pass from the needle over the coagulated parts to the noncoagulated tissue beyond, indicating the complete drying of the former. Some growths simply shrivel into a dry mass. When sparking appears all over inside of the growth, the current should be turned off; the dead mass must be curetted or cut away, because otherwise it acts as an insulator. If at the base or edges destruction seems incomplete, the current is reapplied.

In treating malignancies one should aim to destroy all suspicious tissue at one sitting. New growths and other lesions located on cutaneous surfaces, once they are devitalized by either electrodesiccation or electrocoagulation, should be removed, as a rule, immediately, by cutting or curettage. Any oozing in normal tissue which might be due to the curetting or other methods of removing the tumor should be lightly desiccated. A dry dressing is to be applied after the operation.

It is one of the limitations of electrocoagulation that in destroying large masses even experienced surgeons cannot always exactly gauge the depth of destruction. There is no possibility of differentiating adjacent vital structures (nerves, blood-vessels). Too heavy a current applied near large blood-vessels and other vital structures may result in serious secondary hemorrhage or other complications. When near bony structures, destruction of the periosteum cannot always be avoided, and this may entail necrosis of the bone and considerable delay in healing. The premature separation of sloughs also may cause secondary hemorrhage.

On mucous membranes, due to the greater vascularity, there is a greater possibility of a secondary hemorrhage; for this reason it is advisable to let the devitalized tissue slough off by degrees. This will take a variable time, according to the character of the destroyed tissue and its location. In mucous membranes like the mouth, frequent antiseptic washes should be used.

Postoperative pain is often comparatively little, due to destruction of nerve endings and the sealing up of all possible sources of infection. Depending on the size and depth of the lesion, healing may be complete in from two to four weeks. The rapidity with which healthy granulations spring up after the slough has been removed is praised as a great advantage of electrocoagulation over roentgen-rays. Occasionally, indolent, slow-healing ulcers and inflammation of the surrounding tissues follow, usually due to overtreatment and needless irritation of the surrounding healthy tissue. Bone and cartilage take the longest time to sequestrate.

The Use of Biterminal Electrodes.—In recent years there has been an increasing use of the biterminal method of coagulation. Two insulated needles in a suitable holder are connected separately to the terminals of the apparatus. Each of the needle-points represents an active electrode and no dispersive electrode is used. In this method coagulation takes place only between and around the two needle-points and very little current is employed. For destruction of tonsillar tabs or parts of tonsils, small tumors of the skin and mucous membranes, notably hemorrhoids, this technique is quite useful. For fine coagulation in neurosurgery a two-point coagulation forceps has been described by Greenwood.[7]

Care must be taken to avoid excess current. This leads to arcing between the points and the "burning" out of the electrode.

TECHNIQUE OF ELECTROSURGICAL CUTTING

Electrodes.—A thin flat blade or needle serves as the active electrode and the usual large metal plate as the dispersing electrode. The thinner the edge of the cutting electrode with the same current strength and speed of cutting, the less coagulation occurs along the line of separation. If primary union is desired, a thin needle or very thin blade should be used for skin incision. Large needles are used for heavier coagulation and hemostasis, such as incising vascular tumors, the lip or tongue or lung abscesses. Thin loops, oval and round, are used for taking biopsy specimens or piecemeal removal of other tissue. Conization electrodes serve for excision of tissue from the cervix, and other special electrodes for underwater cutting. (Fig. 196.)

Experimental Practice.—The equipment necessary is the same as for experimental coagulation except that a cutting blade as well as a steel needle should be employed as the active electrode. Lay the piece of steak on the dispersive plate just as in electrocoagulation.

1. Adjust the controls to about one-third of the available current strength, contact the *tip* of the cutting blade with the meat. Practice turning on the current simultaneously with the moving of the active electrode. Note that it will move along the meat with practically no resistance. Turn off the current before the electrode has reached the end of the cut. There should be an even area of dehydration along the entire cut with no evidence of deeper coagulation.

2. Turn on the current before the electrode contacts with the tissue and take the electrode off before the current is turned off. In both instances there will be a flash on contact and a marked area of coagulation where the blade starts or ends its incision. An uneven line of dehydration and the excess amount of coagulated tissue often interferes with primary union.

3. Touch the meat with the entire edge of the cutting electrode instead of the tip only. A wide area of coagulation will occur under the area of the first contact and there will be a delay in straight cutting. Note the same occurrence if the cutting blade approaches the meat sidewise. Operators of cutting apparatus must learn to synchronize movement of the electrode with closing and opening the electrical circuit and must learn to use only the tip of the electrode for incision directly across the tissues.

4. Repeat these experiments with a straight needle as an active electrode instead of the cutting blade. Note that with the same current strength there will be a greater depth of dehydration, due to the greater density of current around the tip.

5. Repeat these experiments on fatty, fibrous and cartilaginous tissue. Note that it requires different settings of power to proceed with equal ease. Note that when cutting through considerable thickness of fat, the electrode does not cut readily and "boiling" of fatty tissue occurs. Learn to overcome this by very rapid incision at moderate strength of current, making many shallow cuts rather than a few deep ones. Keeping up traction on both edges of the cut further diminishes boiling of fatty tissues.

Operative Technique.—Upon proper adjusting of the strength of the current and with suitable dexterity in the speed of cutting, the active electrode sears its way through the tissues meeting with almost no resistance. The surgeon has to acquire a new sense in applying the electrode delicately and drawing it rapidly through or over the tissues. Only a tiny arc should be maintained between the electrode and the tissues. A thin film of coagulation forms along either side of the incision, sealing the small blood-vessels and the lymphatics. The edges separated by the "electric knife" can be sutured, and healing by first intention will follow, provided that the proper technique was used and there was neither charring nor deep coagulation of neighboring tissues.

The cardinal rule in regulating the strength of current is that one should always use the lowest strength that cuts freely to the desired depth, and one should choose the size and shape of the electrode according to the electrical resistance of tissue under the electric knife. Fat, cartilage, dry sclerotic tissue require more current. Fatty tissue is likely to boil under heavy current; hence rapid, shallow cuts are more suitable for subsequent union. It is necessary to understand current characteristics to be able to meet varying conditions.

As a matter of general policy it appears more advisable to use ordinary scalpel cutting for incision of tissues of high electrical resistance, such as the skin, fasciæ and tendons; chances of rapid and firm healing are better if there is less necrosis along the lines of incision. Unless one has acquired delicate control over the coagulating effects of the cutting current, the percentage of undisturbed primary healing after orthodox scalpel incision in the enumerated tissues is greater.

Sudden muscular twitches in the field of operation occur occasionally. They have been attributed by some physicians to a faradic effect through a supposedly badly adjusted apparatus. As a matter of fact, they are due to the stimulating effect of sudden intense heat on motor nerves in the operating field. The only way to minimize them is to use the least possible amount of current strength in such location. It has been suggested also to maintain traction on each side of the line of incision, so as to keep the affected muscles under tension while the cutting current is on.

Hemostasis.—The superiority of electric cutting over the non-electric scalpel is at once evident in the operation on the liver, spleen, kidney, lung, thyroid and the brain with their extensive capillary beds. The sealing of all small blood-vessels gives a clearer and better operating field, a much faster operating time. If a larger vessel is severed and is not sealed by the cutting current, it should be grasped with the usual hemostatic forceps. At any convenient time during the operation, the clamp held in the operator's left hand should be touched 1 or 2 inches from its end by the active electrode—not with its tip, because the heavy sparking may damage the edge. (Fig. 203.) Within one or two seconds a thin visible zone of coagulation appears around the tip of the hemostat; the circuit should be now broken and the hemostat removed. This electrohemostasis results in saving of time and ligature material; on account of the lesser amount of foreign material in the wound, the wound heals quicker, there is very little hemorrhage during the operation and practically none afterward; the wound is sterile and the danger of metastasis is much lessened.

In using this technique care should be taken to avoid grasping excess tissue about the vessel itself within the jaws of the artery clamp so that excessive necrosis in surrounding tissue does not occur.

Cushing[3] developed a special technique for the sealing of smaller blood-vessels which are exposed and free from organs, such as occur in the brain. A ball electrode, about $\frac{1}{8}$ inch in diameter, is employed as the active electrode with the coagulating current. Beginning with a clamped end of the blood-vessel, this electrode is applied in a series of short strokes along the surface of the blood-vessel, at a current strength commensurate with the size of the vessel. This results in pushing the blood back in the lumen and in the gradual collapse and shrinkage of the vessel wall.

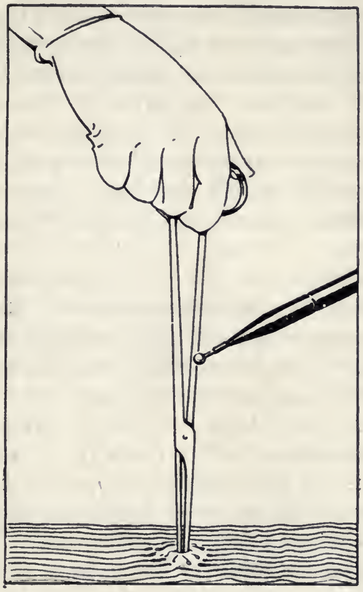

FIG. 203.—Hemostasis by electrocoagulation.

Underwater Cutting.—Underwater cutting is a modification of electrical cutting which enables excision of tumors in the bladder and the prostate. It is done with the usual biterminal technique, but the active electrode must be insulated as far as the cutting tip to insure minimum of current leakage through the conductive medium of water. There is also need of considerable current strength to make up for this inevitable leakage. The ordinary uninsulated electrosurgical knife or loop operating from a low power machine cannot cut under water.

Conization.—Conization is a special technique developed by Hyams[11] for destruction and removal of infected cervical tissue by the cutting current. The active electrode is a fine tungsten wire stretched over a silicon tube in the form of an arc which conforms to the contour of the cervical canal. With a current of suitable strength the electrode is rotated completely around the cervix and the wire cuts a core of cervical mucosa. (See Chapter on gynecological conditions.)

Bipolar Cutting.—Bipolar cutting, similar to bipolar coagulation is advocated by Guleke[8] in brain operations because some of the inevitable by-effects of current dispersion through the sensitive tissues can be avoided if the current is confined between two active electrodes.

ANESTHESIA IN ELECTROSURGERY

For most of the applications of electrodesiccation a local anesthetic is not necessary. In especially sensitive patients or for larger areas, the local injection of procaine or novocaine is satisfactory. A 2 per cent solution is recommended in preference to 0.5 or 1 per cent so commonly used in scalpel surgery. A generous amount is injected, for the heat of the current frequently passes out beyond the area blocked off if a weak solution or scanty amount is employed.

In conditions requiring general anesthesia there is a danger of explosion when ethylene is used in connection with electrosurgery. Even the smallest spark may cause a violent explosion. Mock[18] states that one should refuse to do electrosurgery if ethylene was given in the same operating room within the previous thirty minutes. On the other hand he does not hesitate to use either ether or nitrous oxide anesthesia in all electrosurgical operations except those about the mouth and face. The combination of nitrous oxide and ether anesthesia should not be used because, when combined, they are more explosive.

Breast and other operations on the trunk, abdomen, pelvis and extremities are performed under ether anesthesia, provided the anesthetist remains back of a screen and reasonable precautions are taken not to spill the ether or scatter gauze or towels saturated with ether about the operating room, or near the electrosurgical apparatus or electrodes.

Since, however, there have been occasional serious accidents resulting from ignition and explosion of ether vapor it is better to avoid its use when possible. The use of local infiltration about or under small lesions and field-block or nerve-block in larger lesions, is the most desirable technique for operations that can be performed under limited anesthesia in short time. Spinal or sacral epidural block is an admirable technique for larger lesions in the lower extremities or perineal area. For the upper trunk, head, neck and breast, colonic or intravenous anesthesia is most satisfactory when novocaine or nitrous oxide is inadequate. Colonic instillations of avertin, evipal, paraldehyde and intravenous evipal or pentothal are becoming more generally recognized as excellent techniques as anesthetists become more familiar with their administration.

In the inhalation group of anesthetics it must be remembered that the mixture of nitrous oxide and oxygen is not inflammable, but when mixed with ether vapor the gases may be ignited by sparks or glowing exposed electric cautery. This is likewise true of ethylene, cyclopropane and the vapor of ethyl chloride, either used alone or in combination with any other gas.

CLINICAL USES OF ELECTROSURGERY

The employment of electrosurgical methods can be considered from two viewpoints, that of the general practitioner and that of the general surgeon or specialist. For the general practitioner, the skilful use of electrodesiccation, based on accurate diagnosis, offers the possibility of treating a large number of minor surgical conditions. For the general surgeon and specialist the use of electrocoagulation combined with electric cutting has made possible decided advances in the surgical treatment of parenchymatous organs, due to decrease of bleeding, increased speed of operation and decrease of postoperative shock and pain. It affords also a new technique in attacking malignant disease.

Uses of Electrodesiccation.—For the destruction of superficial lesions of small size, where good cosmetic effects are essential and also where the delicacy of the tissue makes surgical intervention difficult, electrodesiccation is the method of choice. Its principal indications and some of the special points of technique are herewith enumerated.

Skin Conditions.—Electrodesiccation may be employed in treatment of warts, moles, small congenital angiomas, mollusca contagiosa, tattoo marks, nævus vasculosus and pigmentosus, xanthomas, lupus vulgaris and erythematosus, keratoses and precancerous dermatoses. Most of these conditions and the points of technique are discussed in the Chapter on skin conditions.

Epilation or removal of superfluous hair by electrodesiccation is a well-established procedure but it requires an apparatus or a suitably decreased output producing a very fine current within delicate control. (Fig. 197.) It enables destruction of hair follicles in a few seconds in rapid succession and with a minimum of after-effect. For full description of technique see Chapter on skin conditions.

Other locations suitable for electrodesiccation are:

Mucous Membranes: papillomata and other benign growths of the mouth, vocal cords and bladder, leukoplakia, selected cases of infected tonsils and other nose and throat conditions (Chapter on nose and throat conditions), epulis and ranula.

Eye Lesions: corneal ulcer, granular conjunctivitis, trachoma, pterygium and chalazion. (Chapter on eye conditions.)

Gynecological Conditions: skenitis, urethral caruncle and other benign vascular tumors in urethral orifices, condylomata of the vulva, vaginal cysts, cervical cysts, and erosions, nabothian cysts, cervical polyps and other benign growths of the cervix (Chapter on gynecological conditions).

Proctological Conditions: papilloma, selected cases of hemorrhoids, anal fissures, pruritus ani (Chapter on proctological conditions).

Uses of Electrocoagulation and Electrosection.—Electrocoagulation may be employed as a matter of choice for any of the conditions enumerated. It supplants desiccation in the destruction of large tumors or in securing hemostasis. Electrocoagulation combined with cutting has evolved a new technique in the treatment of accessible malignancies. In all larger size epitheliomas, as well as in all other new growths of a frankly or potentially malignant character, it not only rapidly destroys all accessible tissue but also can be used to "circumvallate" the diseased tissue by a coagulation ring in the adjoining healthy tissue, thus separating it from the rest of the organism with little risk of producing metastasis.

In the treatment of any form of malignancy surgical judgment and broad experience are needed to determine whether electrocoagulation alone or the combination with the cutting current is advisable or whether the knife, roentgen-rays or radium should be employed. According to Clark, electrothermic destruction should be used alone only in localized tumors of a type which does not tend to metastasize.

The field of electric cutting, combined with electrocoagulation was outlined by Kelly[12] as follows:

"Various malignancies about face, lips, mouth, tongue, fauces.

"For carbuncles it renders signal services in exsecting the diseased area, leaving a clean, sound, aseptic, rapidly healing wound; in fact, it undoubtedly replaces the actual cautery.

"In malignancy of the skin in all parts of the body, electrosurgery is second only to radium; it supersedes radium in nevi. Often when the use either of the roentgen-ray or radium has been overdone, and there still remains a sclerosed or an extensively ulcerated mass, nothing approaches the efficiency of the exsections of electrosurgery.

"Epitheliomata of the dorsum of hand or wrist, even when the growths extend into the tendons, are admirably handled by electrosurgery which is secondary only to radium well managed.

"For certain breast cases it is supreme, especially in the presence of nodular, ulcerated, massive scirrhous breasts, when there is not a shadow of a hope of a successful removal by classical methods. In such cases electrosurgical extirpation of the mass often proves of inestimable value in stopping the pain and the discharges, as well as in freeing the poor victim of the unsightly reminder of a doom daily approaching.

"Malignancies about the abdomen offer a fertile field for electrosurgery. We can destroy papillomatous ovarian implants faster than it can be stated. Small areas of carcinoma are readily destroyed and left where found, while a scirrhous nodule in the intestinal tract can be widely destroyed.

"Malignant vulvar disease should always be removed by electrosurgery and any inguinal glands sparked out of existence.

"In experiments on the liver and kidney, Ward and Pearse have resected portions of both organs with a marked lessening of the hemorrhage. In the liver there was practically no bleeding during excision of a complete lobe. In nephrotomy and partial nephrectomy, in spite of the large arterial supply of the kidney bleeding was markedly diminished in the peripheral areas. In the neighborhood of the pelvis, the larger vessels required clamping and coagulation.

"Electrosurgery is opening up a large field in brain work as it will in spinal cord surgery. In the brain, as shown by Cushing, electrosurgery is of the greatest value in opening up the meninges, in making safe a passage to an abscess, and above all in the effective handling of hemorrhage. It also enlarges the field of control over malignancy."

Electric cutting methods have been generally adopted in the treatment of prostatic obstruction. McCarthy[16] and others developed ingenious instruments and methods for employing the underwater cutting current. Any desired amount of prostatic tissue may be removed under vision by electrosurgery, without bleeding, with a shorter period of hospitalization, with elimination of shock and with avoidance of permanent suprapubic drainage. (See Chapter on genito-urinary conditions.)

Conization of the cervix has been found valuable in expert hands for the treatment of selected cases of chronic endocervicitis and for biopsy of cervical tissue. (See Chapter on gynecological conditions.)

In lung surgery new possibilities for removal of lung tissue and severing adhesions have been shown (Matson[17]). In goiter surgery by electrical methods the shortening of the operative period and the absence of a severe reaction during convalescence have been reported by Mock.[18]

In nose and throat work, electrical cutting, coagulation and desiccation have become part of the routine work.

In ophthalmology retinal detachment has been treated with multiple diathermic puncture. Complete exenteration was done by electrosurgery in extensive radioresistant cancer of the orbit. Electrocoagulation of the choroid plexus in infantile hydrocephalus was developed by Putnam[20] and others.

Electrosurgical excisional biopsy according to Kime[15] is the method of choice for all skin lesions suspected of being cancerous. The method may be used on any comparatively small neoplasm (less than 3 cm. in diameter and 1 cm. depth) which is readily accessible. Local anesthesia is always used. The growth is completely excised by the cutting current and the base sealed by hemostat coagulation. The tissue excised en block is suitable for histologic study. Kime found the method satisfactory in 98 per cent of 392 malignant epitheliomas followed through the five to ten year period. The list of conditions amenable to cure by electrosurgical biopsy has been given by Kime[14] as follows: Irritated blue-black moles, papillomas, senile keratoses, leukoplakia, senile verrucæ, cutaneous horns, cicatrices following old burns, keratotic and telangiectatic radiodermatoses and areas of radionecrosis following radium or roentgen-ray burns and oil gland tumors and cysts. Cervical erosions, cervical polyps, urethral carbuncles, cysts of the female external genitals, inclusion and dermoid cysts, sweat gland adenomas, glomus tumors, hemolymphangiomas and endotheliomas. Malignant neoplasms amenable to electrosurgical excisional biopsy include various basal cell and squamous cell carcinomas, melanomas and adenocarcinomas.

Critique.—Mock's[18] conclusions as to the present status of electrosurgery are as follows:

"1. Electrosurgery offers a distinct advantage over scalpel surgery in a limited number of surgical conditions.

"2. Surgeons must understand the differences between the dehydrating, coagulating and cutting currents and must learn through much experimentation how to control and use these various currents before attempting to do electrosurgery.

"3. Knowledge in the use of electrosurgery is of secondary importance to surgical experience and judgment. The possession of an electrosurgery apparatus and a little instruction by a manufacturer's agent does not fit one to attempt surgical operations by this method. No physician not thoroughly trained in scalpel surgery should attempt electrosurgery.

"4. Electrosurgery is useful in many operations in the various fields of special surgery. Here again the specialist's knowledge and surgical experience are of paramount importance before attempting to use electrosurgery.

"5. Electrosurgery is the best means of attacking malignant lesions of the skin, breast, the various orifices, and even the deeper malignant lesions after they have been exposed by scalpel surgery. It has proved of great value in neurologic, thoracic, genito-urinary, skin and thyroid surgery. It has a limited field of usefulness in many of the other specialties."

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CHAPTER XIV

ELECTRICAL INJURIES

Accidents During Electrotherapy. Causes: The Equation of the Operator, of the Patient, and of Apparatus. Burns. Electric Shock. Mechanical Injuries. Medicolegal Aspects. Accidents in Homes and Industry. Injuries From Lightning.

ELECTRICAL energy is an obedient and accommodating servant and is indispensable as the prime mover in innumerable phases of industry, travel, home life and likewise in the art of healing. But, like any other powerful agent, it must be employed with care and a knowledge of how to prevent ill-effects from its use.

Accidental injuries most frequently occur in connection with the use of electricity in homes and industries, but they also occur from time to time during the therapeutic application of electricity. They consist of either local injuries, that is, burns of varying extent; or they may be general in their effects—electric shock or electrocution. At times a combination of both local and general effects may occur. Local injuries are usually caused by a current of small voltage and small amperage, such as used in electrotherapy. General or lethal effects may occur when a voltage large enough to overcome the resistance of the tissues is combined with an excessive amperage, as is the case in high-voltage electrical contacts, or else when the resistance of the tissues is much decreased, as with a person in a bath or when standing on a wet floor.

ACCIDENTS DURING ELECTROTHERAPY*

"Primum non nocere"—first of all do not cause any harm—is the classic Latin pronouncement as to the duties of the physician toward his patient. Legal authorities tell us that the average physician when taking charge of a patient must have the reasonable degree of learning and skill that is ordinarily possessed by physicians and surgeons in the locality where he practices. On the other hand, "a physician who holds himself out as being specially versed in some phase of medicine is required to possess special knowledge and skill, not merely such knowledge and skill as the average physician has but such as is possessed by the average specialist.[7]

"The modern development of medicine and surgery with the tendency to the extended use of apparatus for diagnostic and therapeutic purposes has made these demands much more complicated. The doctor is not only supposed to be a diagnostician and have a good knowledge of the action of drugs and of the principles of surgery, but is also expected to be a mechanic and somewhat of an electrotechnician. He must be able to supervise and direct his nurses and other technical personnel and is liable for improper treatment on their part; yet no matter how skilled the physician or his personnel, accidents are unavoidable from time to time. A patient sneezes and the sudden muscular action dislodges a pair of electrodes over the

* From a paper of the author read before the Society of Medical Jurisprudence, New York, and reprinted from the Journal of the American Medical Association, **100**, 107, 1933.

shoulder or causes one of the cord tips to slip out from its insertion; in both cases the current may be shut off almost immediately by the physician or his nurse, yet a certain amount of damage will occur.

"Considering the widespread application of electricity for therapeutic purposes, there is an almost negligible amount of injury caused by it; this, of course, is due to the safe and efficient types of apparatus and to the careful technique used by physicians and technicians in the application of the various currents. Nevertheless, accidents from time to time are unavoidable. The causes which lead to their occurrence can be classified in three broad groups: (1) the equation of the operator: improper technique or inattention; (2) the equation of the patient: unusual sensitiveness or idiosyncrasy, lack of coöperation, contributory negligence; (3) the equation of apparatus and accessories: faulty construction or mechanical breakdown. Many injuries are attributable to an unfortunate combination of causes; as long as the general rules of safe technique are followed, a single cause usually does not lead to any serious injury.

"1. **The Equation of the Operator.**—The operator of any piece of apparatus used for diagnosis and treatment must have a fair conception of its working mechanism and have full knowledge of the technique of its application. Such knowledge should be acquired on the basis of clinical instruction and experience and not from the salesman of apparatus. The operator of any apparatus must know how the energy output of that apparatus is controlled, and how it will affect the parts of the body subject to its influence. He must know how to apply and hold electrodes in good position and must know how to proceed with the treatment to the degree of maximum efficiency without discomfort to the patient. He must be familiar with the danger signals of chemical or heat burns. He must take nothing for granted, so far as the patient is concerned, and use all reasonable precautions to avoid accidents, save for wilful acts or neglect of the patient in disregarding properly understood warnings.

"No complaint of a patient during examination or treatment, no matter how trivial, should ever be lightly brushed aside. Proper technique requires that the patient is made comfortable and remains so during the entire treatment with the part under treatment well supported and relaxed; also in a busy office, that a time clock or other controlling device be used to cut off the current automatically at the expiration of the treatment period.

"It is an important rule of the routine of any office that the parts receiving treatment be carefully inspected before and after each application, any changes being noted. One occasionally hears complaints made by patients that they noticed a blister on returning home after an electric treatment. If thorough routine inspection of the parts after any treatment is consistently carried out and no changes are found in the office, one can safely assert that the lesion complained of did not originate from the treatment there, for any damage to the skin from a galvanic, diathermic or other electric current would produce enough change in the tissues to be visible immediately and not hours afterward. Burns due to heat treatment by lamps as a rule also show up immediately, but occasionally a blister may develop overnight, following a long heat exposure. Such lesions are due to the raising of the superficial epithelium by an exudation of lymph, but being quite superficial they dry up in a day or two and never can give rise to a serious complaint. Burns after ultraviolet exposure take twenty-four to seventy-two hours to develop fully, while roentgen-ray burns are well known to take weeks to develop. The chief protection of the operator in all cases is an indisputable record as to a generally correct technique.

"A final point of safe technique is never to leave a patient alone during a treatment in which the slipping of a conducting cord or a fastening clip or of any of the electrodes could give rise to an immediate burn. Either the physician or his trained office assistants must be ready at all times to decrease the current strength or to shut it off altogether if the patient complains or there is any possible sign of danger. There are timing devices available which, connected to the apparatus, enable the patient to shut off the current by simply pulling a cord; simultaneously a gong summons the operator. This is a perfectly safe arrangement, provided the patient is told how to use it.

"2. **Equation of the Patient.**—The physical and mental equation of the patient is of paramount importance in administering treatments. A safe technique in many instances depends on the patient's coöperation in reporting at once an unpleasant sensation or a feeling of excessive heat, or in keeping still in a certain position; if patients fail to comprehend or follow these instructions their lack of attention or misunderstanding becomes a contributory factor in accidental injuries. In long-wave diathermy and galvanic treatments the theoretical amount of current toleration is estimated according to the size of the active electrode. The meter reading of the apparatus mainly serves as a safeguard as to the maximum amount that may be administered. The patient's comfortable toleration is always the principal guide. In the technique of longitudinal heating by diathermy, instead of burning and pain, a feeling of tension in the wrist or ankle serves as a subjective warning sign.

"The individual skin sensitiveness toward ultraviolet radiation in those of fair complexion, blondes and old persons is well known and must always receive consideration. The minimal dose within safe toleration of such patients can be determined only by preliminary testing over a small area of the skin.

"3. **Equation of the Apparatus.**—Apparatus must be in good working order as an essential for the safe application of any kind of treatment. At the same time, any apparatus used day by day is apt to get out of order through continued friction or wear, such as slow disintegration of insulation due to heat, or through defective construction. When a patient is treated by an apparatus with an undetected defect, a minor mishap or a real tragedy may occur. Kowarschik[6] reported a case in which galvanic treatment for facial paralysis was administered from a new type vacuum tube galvanic generator. One electrode in the form of a half mask was placed over the face, the other over the forearm. A small, cheap circular wire rheostat, similar to the control on radio boards, was used to regulate the strength of the current. At the end of the treatment the assistant slowly turned this control back to zero, and just at that moment the patient cried aloud and fell unconscious to the floor as if struck by an electric bolt. The cause for the profound electric shock was found in the poor construction of the rheostat which swung over from the zero position to 360 degrees—that of full strength, without an intervening catch. The patient thus suddenly received the full strength of the current through the head. He recovered subsequently."

Such extreme cases are, fortunately, rare in this country, but should serve as a warning to buy only apparatus of standard make and from a responsible manufacturer. Cheap appliances of flimsy make may readily give rise to similar accidents. Apparatus must be kept in good working order by regular frequent inspection and by immediately correcting any trouble, no matter how trivial. It is bad psychology ever to discuss any trouble with apparatus before a patient. Some patients are apprehensive when receiving electrical treatment for the first time and any doubts expressed about the smooth working of the apparatus may cause them to jump, throw off electrodes at the slightest provocation, and thereby lead to a real injury.

BURNS*

Burns are always due to an undesired excess of thermal energy applied through the medium of electricity, radiation, water, paraffin, to the skin or mucous membrane. In the course of electrosurgery excessive current density is purposely employed in order to produce tissue destruction and most of the time the destructive effect is not due to the absolute strength of the current, but rather to the disproportion of the area of the active and dispersive electrodes. A galvanic current of a few milliamperes strength or a diathermy current of 200 or 300 milliamperes may cause destruction if concentrated to a small area.

Pathology.—According to the form of energy employed, burns are caused by thermal, electrochemical or photochemical tissue destruction, and their prevention and treatment varies accordingly. The common feature of all of these injuries is that they are due to the devitalization or destruction of tissue; that their appearance may be immediate or take several hours or days. Their clinical appearance may vary from a passing erythema to blistering of superficial layers of the skin or deep tissue coagulation with subsequent ulcer formation; they are slow of healing, may become infected and according to the depth and the location of destruction, may be followed at times by extensive, unsightly scarring.

Burns from Heat Lamps.—Exposure to infrared or visible radiation results normally in an erythemal response consisting of single dark red spots or a confluent network of these, and occurs according to the distance from the lamp, the wattage of the bulb, and the type of reflector, and the sensitivity of the patient. Excess radiation, or hypersensitivity, or other causes, may produce, after the initial erythema, wheal formation, local edema and eventually blistering. Sometimes these blisters only develop overnight. Excess radiation in normal patients always gives rise to a varying degree of burning sensation. Unfortunately, there are quite a few persons who, when receiving treatment for the first time, think, in spite of warning to the contrary, that a severe burning sensation is part of an effective treatment and become blistered due to their own contributory negligence.

Burns from Diathermy.—Undue current density of either long-wave or short-wave diathermy may cause drying or coagulation of tissue such as is produced intentionally by electrodesiccation or coagulation. According to the contact surface between the active electrode and the skin and the strength and duration of the current flow, the effects vary from a whitish

* Reprinted with permission from International Clinics.[5]

discoloration of the epidermis at one or more points to actual formation of blisters and changes to a considerable depth in the color and consistency of the skin. The current flow is fortunately usually cut short, as most of these burns are preceded by an intense reaction of pain, so that the patient usually cries out for help or shakes off the electrodes. At times, however, the burns may happen unnoticed in people with defective heat sensation.

In the later course of diathermy burns, should only the superficial epithelium have been seared, this peels off in a few days, leaving no trace of a lesion. In patients with a marked exudative diathesis a large wheal may appear immediately or a few hours later over an overheated area, only to disappear by next morning almost entirely, or leave only a small erythematous area or perhaps a small blister. In certain instances, however, there is subsequent sloughing and ulceration, possibly with exposure of subcutaneous tissues, of muscles, even of bone. Another form of diathermic burn is fat coagulation in the subcutaneous tissue, usually occurring in adipose women. As a result, one or more painful nodules appear under the skin, however, they usually decrease and absorb in a few weeks without any further damage or permanent sign.

The advent of short-wave diathermy with its simplified and safer technique of spaced condenser electrodes or the induction coil has done away with most of the burns due to direct metal contact. Because of the relatively less heating of the skin there is also less occasion of overheating the skin, but the possibility still exists, and burns by short-wave treatment have occurred when warning signs were disregarded.

Burns from Galvanism.—In galvanic treatment or ion transfer with electrophoretic drugs, if the bare metal electrode or any corner of it comes into contact with the skin, or if the pad is too thin or not sufficiently wet, or if there is a rent in the wrappings for ion transfer, or a scratch in the skin, there may be direct chemical action from either the positive or negative pole, through the metal plate or due to excess density of the current itself which if not detected in time, causes a burn. Galvanic burns develop, unfortunately, often without a sensation of excess burning or pain, owing to the small amount of current employed. After removal of the electrode or the wrappings for ion transfer only an excessive erythema over a small area or a slight wheal formation may show; both of these may last several hours and disappear next day. In the next degree of damage there may be blister formation of varying size and shape; these blisters may be single or confluent and are usually painless. In a day or two a red line of inflammation appears and the blister breaks, leaving an open ulcer. Should several blisters form, a large denuded area of varying depth may develop and this, due to the usual secondary infection, as a rule, becomes quite painful and heals slowly.

Burns from Ultraviolet.—These burns differ from other burns, inasmuch as, first of all, a mild degree of "sunburn" is a normal and desired reaction of the average treatment with ultraviolet; second, hypersensitivity plays a definite rôle in the occurence of these burns when they are not due to simple overdosage. Certain drugs or substances when circulating in the blood or applied to the skin cause a marked "photocatalytic" reaction. Among these photosensitizers are endocrines, fluorescent dyes, heavy metals, and also, as recently claimed, sulfanilamide. There are also a few individuals with inborn sensitivity to both sunlight and artificial ultraviolet. The results of an increased reaction in such cases vary all the way from a severe itching to a rapidly developing dermatitis, edema of the skin, formation of bullæ, fever and general malaise. Overdosage in normal individuals such as occurs when a careless operator forgets to turn off the ultraviolet lamp in time, or an individual falls asleep under a self-administered lamp treatment, shows the same variation. The severe general reaction in each case is due to the flooding of the blood stream with the split protein products of the skin, a severe "protein shock." In extreme cases, gastric and duodenal ulceration may also occur, with a lethal outcome. Fortunately, in the course of ordinary treatments severe reactions are extremely rare because it has been estimated that a margin of safety as great as 50 per cent against overdosage exists.

Treatment of burns occurring during electrical treatment is similar to that of any other burn. After antiseptic cleansing the first dressing is made with a boric-acid ointment. If on the next day the burn is found to be more or less dry and the surface of the skin is not broken a dusting powder with dry gauze held by adhesive plaster is all that is needed. When the burn is a large one and ulcerated, the boric-acid ointment dressing should be continued. Daily exposure to the rays of an infrared or incandescent lamp for one-half hour or more promotes nutrition and speeds up healing. The healing of small burns can also be speeded up by daily short exposures to ultraviolet irradiation. They should be kept dressed with plain gauze pads soaked in paraffin. (See also Chapter on skin conditions.)

Diffuse dermatitis and severe effects due to a severe ultraviolet reaction must be treated according to general medical principles.

ELECTRIC SHOCK

Electric shock denotes the sudden harmful influence of an electric current to the entire body. Serious shock can never occur during electrical treatments applied with a careful technique. Under rare conditions minor degrees of electrical shock may be caused by the following contingencies:

Low-frequency Current Passing Through Cardiac Area.—In using low-frequency currents, there never should be an electrode over or near the heart, because even a small amount of current passing through the cardiac area may cause fibrillation of the heart and electric shock. This danger to the heart is the reason why, generally speaking, shocks from an alternating current source are more dangerous than from direct current.

Accidental Contact With a Grounded Object.—Touching a water pipe, radiator, electric light socket while undergoing electrical treatment from an apparatus or while immersed in a galvanic bath may cause shock. An apparatus which utilizes the commercial lighting current directly, interposing only a variable resistance, offers this possibility of leakage of ground current to a patient. This danger is best avoided by using ground-free apparatus (motor generators) or else by carefully avoiding any grounded object within the reach of the patient or operator. At any rate, shock caused by such occurrences becomes serious only if a large surface of the body offers good conduction as an electric bath.

Transformer Breakdown.—If a therapeutic current is derived from a high-tension transformer, and during treatment, a breakdown of insulation occurs between the primary and the secondary side of the transformer, there is danger of the high-tension, low-frequency current jumping over to the patient. Such a case occurred in Italy a few years ago when a physician demonstrated to a group of friends the mild heat effects of a high-frequency current, by passing the current through each person using cylindrical metal electrodes held in the hands. When the current was put on in the same manner to a girl aged nineteen years she fell dead. A broken wire in the transformer had caused the high-voltage, low-frequency current to jump over into the high-frequency circuit, there being—contrary to the safe custom—direct (galvanic) coupling between the two sides instead of the safe inductive or magnetic coupling.

MECHANICAL INJURIES

Mechanical injuries may occur in connection with therapeutic procedures when an improperly supported piece of apparatus falls upon the patient and causes a contusion or tear of the skin. The excessive action of mechanical exercising apparatus may cause injury to the skin or a rupture of such organs as the bladder. Among non-electrical procedures, in colonic therapy the now outmoded long stiff colon tubes may cause a rupture of thin-walled diverticula. Manipulation of deformed joints may cause excessive reactions and at times fracture of atrophied bones.

MEDICOLEGAL ASPECTS

Legal authorities tell us that the average physician when taking charge of a patient must have the reasonable degree of learning and skill that is ordinarily possessed by physicians and surgeons in the locality where he practices. On the other hand, a physician who holds himself out as being specially versed in some phase of medicine is required to possess special knowledge and skill, not merely such knowledge and skill as the average physician has but such as is possessed by the average specialist. The law does not compel the physician to be an insurer of good results and does not hold him responsible for an honest error of judgment. However, the law does create a standard of knowledge, skill and diligence and the standard is higher for a specialist than for the practitioner of general medicine and still higher for the specialist of renown than for one in a more modest position. Malpractice suits are based on alleged negligence, carelessness, want of requisite skill and poor judgment. An accident, if it be merely an accident and not the result of any neglect or improper act or neglect, does not form the basis of liability. The statement of an individual or his lawyers that when he went to the doctor he was all right and then came away with a burn, does not prove anything against the doctor. It must be shown that he has done something that is negligent and the patient must have been free from contributory negligence before liability can be established.

The law demands that the patient follow the directions of the physician and do nothing to jeopardize the results; he must coöperate in a manner to help obtain good results and to help to avoid bad results. The patient may be found guilty of contributory negligence.

The employment of technicians in physicians' offices and the institutional work of physicians has also created some definite legal aspects. If an injury has been occasioned by negligent or improper treatment or neglect in an institution, the nurse or technician whose improper act of neglect resulted in the injury is, of course, personally liable. Such liability is, however, rarely enforced because the technician or the nurse is usually not financially responsible. The physician under whose direction treatments are rendered by a nurse or technician is responsible under the doctrine of *respondeat superior*. The physician is not, however, liable for any injury occasioned by an act of the nurse or technician without the scope of their employment, such, for example, as a wilful attack upon a patient. The hospital, if it be an institution organized for profit, would be responsible to the same extent as would be the physician and upon the same principle of *respondeat superior*. If the hospital, however, is a non-profit institution, the hospital is relieved by law from any responsibility.

If the physician sends a nurse or technician in the physician's employ to a patient and makes that nurse or technician his own agent or representative in the treatment of the patient, then the physician is responsible for damages occasioned by the negligent or improper acts or omissions of the nurse or technician, other than for wilful acts of the nurse or technician clearly outside the scope of their employment. If, on the other hand, the physician suggests to the patient that he knows a technician or a nurse, and with the patient's consent undertakes the mechanical details of having the nurse or technician come to the patient's house, thus making the nurse or technician an independent contracting party, the physician is liable only in the event that he has not exercised reasonable care in the selection of the nurse or technician.

Our legal advisers point out two important matters which are often neglected by the average physician. One is the keeping of sufficient or adequate records for the treatment of office cases, even of a minor nature. In most states a malpractice suit can be instituted any time up until two years after the cause of action occurs. Two years after treatment has been administered it is very difficult for a physician to remember anything about it and back up his statements unless he can consult definite records of the case. Another point is that following an accident, should any sort of injury develop, he should freely and fairly deal with the patient and not conceal anything from him.

ELECTRICAL ACCIDENTS IN HOMES AND IN INDUSTRY

The extended use of electricity for lighting and for power requires conduits of large voltage and amperage practically everywhere. If through ignorance or carelessness a person either touches the two poles of the current or touches one pole and the ground he becomes part of a circuit and an accident may happen.

One line of the ordinary 110-volt house current can be safely touched by a person standing in dry shoes upon a dry non-metallic floor; an electrician often tests a lamp socket for live current by putting two fingers against the charged parts, and all he feels is a disagreeable pricking but no shock, on account of the small area of such contact and its great resistance; if he were to continue to keep his fingers in contact, however, he would soon receive a burn.

So far as the general use of electrical appliances in the household is concerned there are two general rules of precaution for everyone. The first is never to touch an electrical appliance while standing in water, on a damp floor, or while any portion of the hand or feet is wet; second, never handle two electrical fixtures at the same time. There is always the danger of a worn-out insulation in one apparatus and, by touching its metallic part while handling another apparatus, there is the chance of a leakage ground current to cause a sudden shock.

Frequent causes of electrical mishaps are: Pulling the metal chain of an electric light and touching with the other hand a pipe, radiator or other grounded metal, or while standing with wet feet upon wet ground or in a bathtub; or touching any part of an electric light fixture and at the same time screwing on a bulb and accidentally touching the metal base of the bulb or the charged part of the socket.

The danger of accidents, of course, is much greater when high-tension currents of thousands of volts are approached; then even the touching of one of the terminals may discharge a fatal current, overcoming the resistance between the person and the ground. Visitors to a high-tension plant should, therefore, stand on dry and insulated platforms as far as possible, and also keep *one* hand *in the pocket.* Lightning, of course, is the electrical discharge of the highest potential, and it may hit and kill under almost any circumstances.

As a result of any of the conditions enumerated, there may occur either external injuries—burns, or a shock to the entire body.

External Injuries.—External injuries are of two kinds. The first variety is caused by the effect of heat due to passage of the current into or out of the skin through the contacting electrode. The heat may be produced within the cutaneous tissues by localized excessive current density continued for some length of time. The second variety is due to an electric arc between the surface of the body and the contacting or nearly contacting electrode, whereby the impact of the arc strikes the body surface. Both of these actions may occur simultaneously and the result may vary from a mild superficial blister to a deeply charred burn, with destruction of tissue.

Jellinek,[2] of Vienna, the foremost student of the pathological effect of electricity, contends that true electrical wounds, due to sudden electrical sparking or contact from high-tension sources, are different from ordinary electric heat or chemical burns. He states that the most striking characteristics of true electrical wounds are their complete painlessness—the retention for days and even weeks of their original appearance, their failure to react upon the tissues in their proximity and the fact that every electric lesion possesses a remarkable tendency to heal. After a period of latency, lasting days or even weeks, large portions of soft tissue in the region of the wound, as well as pieces of bones, may drop spontaneously away without causing any noticeable discomfort, irritation and without producing suppuration.

Based on the character of the electrical wounds just described, Jellinek is in favor of a strictly conservative method of treatment.

Electrical Shock.—Electrical shock is produced by the sudden, powerful influence of an electric current upon the entire body and is characterized by tonic or clonic spasm and rigidity of muscles, including the respiratory muscles during the passage of the current, and may be accompanied by fibrillation, paralysis or entire stoppage of heart action. There may be burns at the places of entry and exit. Shock may be caused by any of the forms of low- and high-tension currents used in industry or homes and by lightning.

Of the two major types of currents, the direct is less dangerous than the alternating, all things being equal. Low-voltage current has a tendency to throw the heart into ventricular fibrillation if the heart is in the path of the electric current in the body. Higher voltage affects the central nervous system, causing an inhibition or block of the respiration center in the brain. High voltage sustained for any appreciable time will cause heart death as well as asphyxial death from respiratory stoppage. Cardiac fibrillation from low voltages is fatal, but respiratory paralysis often associated with high voltages may be overcome by artificial respiration performed until the respiratory center is able to overcome the inhibition and carry on itself. Alternating current produces more severe muscular contractions than direct current; this often results in the victim "freezing" to the electric conductor and being unable to free himself from the current, thereby increasing the duration of time that the current is flowing into his body.

Kennelly[3] states that it is hard to say just where the danger from accidental electric shock commences. It usually depends more upon the conditions of the accidental contact than upon the nature of the circuit with which contact is made. The longer the exposure to the current flow, the less the possibility of resuscitation. Another factor determining the severity of electric shock is the character of the ground connection, *i. e.*, whether wet or dry. The former offers less resistance to the current flow through the skin; the latter offers greater resistance and as a result generates greater heat in the tissues and produces greater destruction. With wet perspiring skin, resistance is low, more current enters the body, and the shock is more severe. A 1000-volt direct current touched briefly by a swiftly moving dry finger may give a much less severe shock than a 110-volt alternating current grasped with a wet hand by a person standing in the water of a well-grounded bathtub.

Williams[8] states that in the last fifteen years there have been many reports about people who seem to die from touching low-voltage alternating current circuits. For a 110-volt circuit to kill it is necessary that the skin be sufficiently moist, that the contact be sufficiently large and that the current pass through the heart muscle in sufficient quantity to throw the ventricles into fibrillation. Not every case of ventricular fibrillation continues to death, but the usual outcome is death. There has been much discussion whether death is due to cardiac fibrillation or to respiratory paralysis caused by the action on the medulla. The prevailing opinion is that cardiac damage is the principal cause, and this view has been corroborated by animal experiments (Koeppen[4]). This fact also explains why artificial respiration will often maintain sufficient circulation to keep the cellular elements of the central nervous system alive.

Immediately following shock respiration may cease while the heart action continues, but this is explained by tonic spasm of the respiratory muscles, and breathing is resumed as soon as the electrical contact ceases. It has been also observed, that respiration continues after the heart has gone into fibrillation or stopped. Instances of the spontaneous resumption of the suspended heart action have been reported, but this never occurs after intervals as long as two minutes.

Treatment.—The first rule is to disengage the victim from the current, either by turning off the power or short-circuiting it. At times it is necessary to pull the victim away from the circuit, and for this purpose, of course, heavy rubber gloves or shoes or any other available insulation shall be used. Many secondary accidents have happened due to the careless haste of would-be rescuers. If no insulating substances are available and, especially, if the ground is wet it is better to attempt dislodging the victim by a non-conducting object, a stick of wood or rubber, or by trying to knock the wire out of his hand.

As to the medical emergency treatment, heart massage applied within five minutes after cessation of heart action has been reported as effective. If there is respiratory paralysis artificial respiration is absolutely necessary, and if kept up long enough it may lead to returning of the heart action. If the heart once begins fibrillation it very seldom recovers. Strychnine, camphor and adrenalin have been recommended intravenously, the latter even intracardially, and accompanied by heart massage. Cardiac stimulation, however, should not delay or interfere with artificial respiration, which should begin without the slightest delay.

Injuries to Eyes.—According to Fisher[1] electric flash or glare injury to the eyes is one of the commonest forms of electrical accident. Flashes occur when metal comes in contact with electric current. An arc is formed which produces a blinding glare of light rich in ultraviolet rays. Rarely, the flash may reach the patient's eyes and produce an actual burn. Usually there is no actual contact with the flash, but the heat and ultraviolet rays may produce reddening of the skin surfaces and the brilliant light causes the pupils to be violently contracted and the mechanism of the eyes to receive a powerful stimulation. Visual purple in the retina of the eye becomes completely blanched, and transitory dimness or fogging of vision results. Generally, within forty-eight hours all symptoms disappear and visual acuity is not disturbed.

Injuries from Lightning.—Persons struck by lightning, an extremely high potential discharge between clouds and the earth, are always subject to electrical shock which is often fatal and, in addition, show local lesions which form a peculiar clinical picture. The markings found upon the skin show a striking resemblance to the trunk and limbs of a tree. These are formed by erythematous skin lesions, dilated capillaries and extravasations, and are evidently due to the distribution of the high-tension electrical discharge along the path of least resistance. These surface markings have no relation to the severity of symptoms produced and if the victim survives usually disappear in a few days. The internal damage and the severity of shock depend upon the organs lying in the path between the entry and the exit of the electrical bolt. Treatment is the same as for shock.

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PART III

Light Therapy

CHAPTER XV

PHYSICS OF RADIANT ENERGY

General Considerations. Theory of Radiant Energy. Classification. Measuring Wave Length. Spectroscopic Comparison. Measuring Radiant Energy. Common Physical Phenomena. The Inverse Square Law. The Angulation of Rays. Penetration. Comparative Physical Effects. Comparative Physiological Effects.

General Considerations.—It was stated that a current of electricity denotes a flow of electrons that is set up by a disturbance of the atomic structure and that takes its path through a set of conductors, called an electrical circuit. The therapeutic effects of the different electrical currents are produced by making the human body part of the path of the electrical circuit.

We are now to present the therapeutic aspects of another broad division of physical science, that of radiant energy. Radiation is the process by which energy is propagated through space. Every substance with a temperature above absolute zero emits radiant energy in the form of heat radiation. When electrical or chemical forces of suitable intensity are applied to various forms of matter, luminous and other forms of radiations are produced. Infrared, luminous and ultraviolet rays all are forms of radiant energy. The common characteristics of all forms of radiant energy are as follows: they are produced by applying electrical and other forces to various forms of matter; they all may be transmitted without the support of a sensible medium; their velocity of travel is equal in vacuum but varies with different media. Their direction of propagation is normally a straight line; they undergo reflection, deflection and absorption by the media. They are designated collectively as electromagnetic radiations.

Light is a form of radiant energy which makes objects visible by stimulating the retina of the eye. Ultraviolet and infrared radiation does not render objects visible. The general term of light therapy or phototherapy by custom also includes the employment of the visible as well as invisible radiations of heat and ultraviolet or actinic rays, because they are all, as a rule, produced at the same time and the therapeutic results are due to their combined effect. The term actino-therapy relates more specifically to the employment of ultraviolet radiation.

The application of radiant energy for the treatment of disease or the stimulation of lagging biological processes forms one of the most interesting and most complex chapters of present-day physical therapy. A maze of clinical and experimental material has been accumulated in recent years on every phase of the subject. For the purpose of this volume only the basic physical and physiological facts and the practical uses of infrared, visible and ultraviolet radiation will be presented. Roentgen-rays and radium, although in a physical sense part of radiant energy, are not included in this consideration because, by well-established custom, they form part of another large special field of the practice of medicine.

TABLE 31.—THE ELECTROMAGNETIC SPECTRUM

Name of subdivision	Frequency in cycles per sec.	Wave length	Sources	Therapeutic classification
		Angstroms		
Cosmic ray		0.001	Interstellar space	None
	10^{21}		atom building	
		0.01		
Gamma rays	10^{20}		Radium compounds	Radium therapy
		0.1	Very short roentgen-	
	10^{19}		rays	
Roentgen-rays		1.0	Collision between	Roentgen-ray
	10^{18}		high speed elec-	therapy
		10.0	trons	
	10^{17}			
		100		
	10^{16}		Gaseous discharges	
Ultraviolet		1000	Incandescent solids	Light therapy
Visible	10^{15}		Visible light	
Infrared		10,000	Hot bodies	Thermo therapy
	10^{14}		Electric oscillators	
		100,000		
	10^{13}	Cm.		
		1.0		
	10^{12}			
Hertzian waves		10	Electric oscillators	No known value
	10^{11}			
		100		
	10^{10}			
Very short radio		1000	Electric oscillators	Short-wave
waves	10^{9}			diathermy
Short radio		10,000	Electric oscillators	Long-wave
	10^{8}			diathermy
		100,000		
Broadcast radio	10^{7}	Meters	Electric oscillators	
		1,000		
	10^{6}			
		10,000		
Long radio	10^{5}		Electric oscillators	None
		100,000		
	10^{4}			
		1,000,000		
Commercial alter-	10^{3}			
nating current		5,000,000	AC dynamo	Electrotherapy

Table 31 shows the subdivision, physical characteristics, sources and therapeutic classification of the entire range of electromagnetic radiations and Figure 205 their relative extent.

Theory of Radiant Energy.—For many years the commonly accepted theory of radiant energy was that electromagnetic radiations give rise to waves of the ether, the theoretical substance which is supposed to be an unbroken entity throughout the universe. This is known as Maxwell's electromagnetic theory, dating back to its announcement by that brilliant physicist, in 1868, when it replaced the age-old "corpuscular" theory of Newton. Newer investigations have led to a return of the old Newtonian conception of light as a definite substance.

According to our present day knowledge a light ray consists of an enormously large number of exceedingly small entities known as *photons*. These photons are produced by profound atomic changes when a swiftly moving electron collides with an atom. The impact transforms the kinetic energy of the electron into a photon. The photon is ejected from a light source at a velocity of 186,000 miles per second in vacuum, which speed it maintains until slowed or stopped by a liquid or solid body. A light source loses weight when it radiates photons. Photons exert a pressure upon any object that they strike for they possess inertia and mass. They, therefore, appear to be material particles but while in flight they exhibit many properties associated with wave forms of energy. The kind of radiation, whether roentgen-ray, ultraviolet, visible or infrared, is associated with the size of the photon. The intensity of light is a measure of the number of photons arriving at a given area per second. The kind of light (wave-length) and the intensity of light (energy per given area per second) are two very important considerations in radiation therapy.

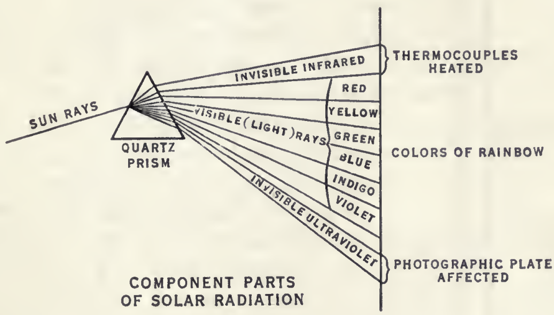

FIG. 204.—Component parts of solar radiation.

Modern physicists, among them Planck, Bohr, Compton and Einstein, evolved ingenious formulas, such as the quantum theory, endeavoring to coördinate in mathematical language the laws of electromagnetism, gravity and light. These formulas belong strictly to the realm of higher mathematics.

Classification of Radiant Energy.—If a beam of white light passes through a glass prism it is not only refracted but also dispersed, and a series of color bands called a spectrum is seen in the prism. Each color corresponds to a different kind of radiation, and their appearance is due to the fact that each is refracted differently. The radiation producing the sensation of red is refracted least, that producing the sensation of violet is refracted most. Beyond the part of the spectrum which affects the retina, the visible rays, there are invisible rays. A thermometer or thermocouple placed beyond the red side of the visible spectrum will register heat, and a sensitive photographic plate held beyond the violet will register chemical changes. The rays beyond the red end are called infrared and those beyond the violet end are known as ultraviolet rays. It has been found that the visible spectrum just described comprises only a small part of the full range of radiant energy. At the red end there exists a large region of radiations designated as infrared, and next to these another very large range of radiations which are used in radio and wireless transmission, the so-called Hertzian waves. (For greater detail see Fig. 205.) At the violet end of the visible spectrum there is the region of ultraviolet rays and beyond these are the roentgen-rays, the gamma rays of radium and some other radiations, not fully explored as yet.

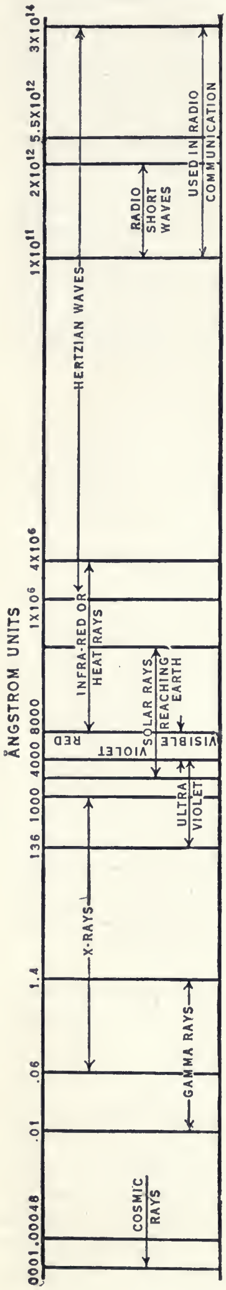

Fig. 205.—Relative extent of electromagnetic spectrum.

The graphic representation of the various energy waves in an ascending order of length is known as the *electromagnetic spectrum.* Lukiesh[4] calculated that if the visible portions were 1 foot long the entire electromagnetic spectrum would be several million miles in length. The basis of comparison of the different parts of the electromagnetic spectrum, besides their physical and physiological effects, is either their wave length (the distance between the crests of two successive waves) or their frequency of vibration. Since all electromagnetic energy travels at the same velocity through vacuum and air, the thermal, luminous, ultraviolet and other rays of the sun strike the earth at approximately the same time. It is evident that the shorter waves must vibrate at a greater frequency and *vice versa.* A homely comparison to visualize this may be a motley army of giants and dwarfs, all under orders to reach the same goal simultaneously; in order to do so the giants step out leisurely, while the dwarfs run and take hundreds of steps for each one of the giants. Dividing 186,000 miles, the uniform speed of radiant energy in vacuum, with the wave length, furnishes the wave frequency or the rate of propulsion per second. One can classify electromagnetic radiations either by their wave length or by their frequency, as is done with the radio waves. (See Chapter X.) The frequencies of the different forms of electromagnetic radiation used in therapy are so very great that it would be impracticable to use such huge figures. The classification of the therapeutic parts of the electromagnetic spectrum, is therefore, made by stating their wave lengths.

Measuring Wave Length.—The standard unit of measuring wave length is the Angstrom unit, proposed first by the Swedish physicist of that name. One Angstrom (abbreviated Å or A.U.) represents $\frac{1}{10,000,000}$ mm., or $\frac{1}{10}$ millimicron (mμ.). Many authors abroad and the United States National Bureau of Standards use the millimicron as the wave length scale. Ten Angstroms correspond to 1 millimicron and one translates millimicrons into Angstroms by multiplying them by 10.

Table 33 shows the wave range and classification of phototherapeutic radiation.

TABLE 32.—WAVE LENGTHS OF RADIATIONS

Radiation	Wave length
Very long electric waves	5,000,000 meters
Hertzian waves	30,000 meters to 1 cm.
Radio waves	30,000 to 10 meters
Commercial broadcast	600 to 200 meters
Amateur broadcast	175 to 20 meters
International broadcast	50 to 15 meters
High-frequency (long-wave diathermy)	300 meters
High-frequency (short-wave diathermy)	30 to 3 meters
Infrared rays	150,000 to 7,7000 A°
Visible rays	7,700 to 3,900 A°
Ultraviolet rays	3,900 to 136 A°
Roentgen rays	136 to 1.4 A°
Gamma rays	1.4 to 0.01 A°

Spectroscopic Comparison.—The term spectrum denotes a charted band of wave lengths of electromagnetic radiation obtained by refraction or diffraction by means of a prism or grating. For determining the wave length transmission of substances in the ultraviolet and visible regions, spectrograms are all that are necessary. Spectra can be classified into three kinds: (1) Continuous spectra are those emitted by incandescent solid substances, such as the sun, the carbon arc lamp and incandescent lamps; they are pure temperature radiations and contain a whole scale of wave lengths, the extent and energy distribution of which depends on the temperature of the hot body. (2) Line spectra are emitted by incandescent vapors and gases, consisting of elementary substances such as mercury vapor; they consist of more or less sharply defined lines which are generally distributed without any apparent regularity. No two elements give spectral lines in exactly the same position in the field and thus an element may be detected merely by observing its spectral lines. The present view is that these lines are produced by the "falling in" of electrons which have been displaced from their normal orbits. (3) Banded spectra are given by compounds when these are dissociated; they always can be resolved into groups of fine lines.

TABLE 33.—RANGE AND CLASSIFICATION OF PHOTOTHERAPEUTIC RADIATION

←1000 to 4000→ Ultraviolet	←4000 to 7800→ Visible light	←7800 to 120,000→ Infrared
	Violet, Blue, Green, Yellow, Orange, Red	
1000, Angstrom units Logarithmic scale, 2000, 3000, 4000	5000, 6000, 7000, 8000	9000, 10000, 20000, 30000, 40000, 50000, 60000, 70000, 80000, 90000, 100000

2200 to 3200	←3200 to 6500→	←6500 to 14000→	←14000 to 120000→
therapeutic ultraviolet	longer wave ultraviolet and visible	penetrating visible and infrared	non-penetrating heat

The frontispiece of this volume shows the comparative spectra of the principal sources of phototherapeutic radiation. It must be strongly emphasized that ordinary spectrograms indicate only the wave lengths available and tell nothing of the light energy at each wave. Comparative spectrograms of the various sources of light, often displayed to unwary physicians by salesmen of lamps, are of little value in judging the efficiency of the light source. Anderson[1] states that on the basis of a spectrogram the ideal ultraviolet source would be the automobile spark plug operated on the automobile ignition system, for it gives a better spectrogram than can be obtained by the quartz mercury arc or any of the carbon arcs. Spectrograms must, therefore, be completed by a chart or table showing the light energy of each wave length. In comparing the graphic representation of energy distribution from various sources at different wave lengths the strength of the activating current must also be stated, for it makes a difference if one set of curves is produced by a 30-ampere source and the other by a 5-ampere source. Comparative spectrograms are of value only if taken under identical conditions as to distance, energy input, exposure-time and on plates of equal sensitivity.

Fig. 206.—Photometer for measuring radiant energy.

Measuring Radiant Energy.—In checking up the efficiency of his sources of radiation the average physician can employ simple clinical tests, as described under ultraviolet radiation, which merely indicate the presence and the gross intensity of certain wave lengths—those causing dermatitis or sunburn. For accurate measurements he will have to depend on the laboratory services furnished by the manufacturer of his lamp or by an independent physicist. For this purpose chemical as well as photoelectric methods have been developed by some investigators; the most effective method appears to be the radiometric one. Its principle is the use of a thermopile connected with a high-sensitivity galvanometer. These radiometers are equally sensitive to all wave lengths of the radiant energy spectrum. All energy, regardless of wave length, when absorbed by the receiving area of the instrument is transformed into heat, the intensity is expressed quantitatively as the number of calories or ergs of heat produced per unit area of absorbing material. The interposition of filters which in turn absorb either the infrared or luminous or ultraviolet energy makes it possible to obtain the percentages of these radiations. These readings are compared to previous calibration against a radiation standard and thus it becomes possible to specify the intensity of the energy incident at the point where measurement is made, in gram calories per square centimeter per second.

Common Physical Phenomena.—The physical phenomena which occur when electromagnetic radiations encounter other substances may be the following:

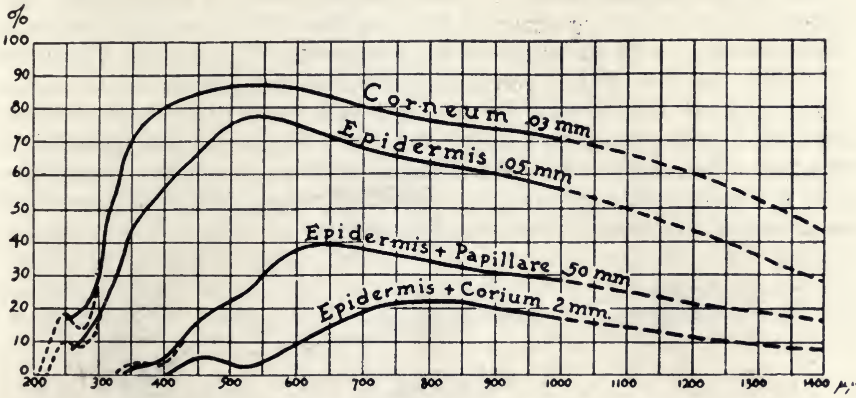

Fig. 207.—Transmission curves for the various skin layers. (Bachem and Reed.)

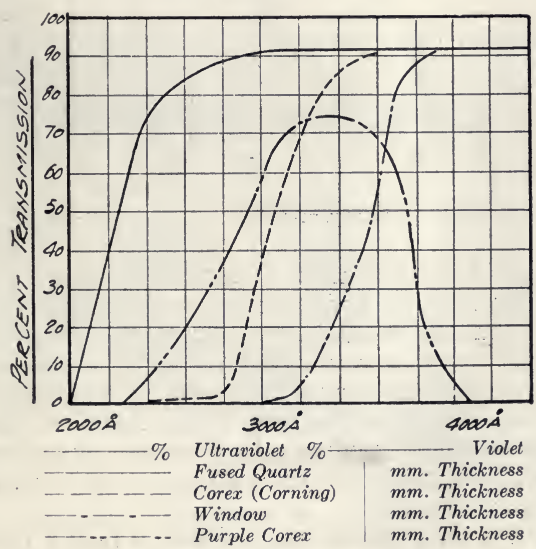

Fig. 208.—Transmission of glasses.

1. The rays are reflected or thrown back by all substances. Snow is an excellent reflector of ultraviolet energy. The reflectors mounted around the various lamps reflect both visible and invisible radiation and add to its amount. When skin scales are present they reflect a certain amount of radiation and the length of exposure has to be somewhat increased.

2. The rays penetrate all substances to some extent. Clear liquids, glass,

quartz are more transparent to light rays than to heat rays. The various layers of the skin and various glasses are variously transparent to certain wave lengths. (Figs. 207, 208.)

3. The rays are absorbed by all substances to a certain extent. Secondary to this absorption, chemical and biological phenomena result, such as fluorescence, phosphorescence, ionization, photoelectric effect and chemical catalysis. The discussion of these purely photophysical effects is beyond the scope of this presentation.

The Inverse Square Law.—In administering radiant energy from any source one must be cognizant of the fact that the intensity of radiation varies inversely with the square of the distance from the source. Figure 209 visualizes this law of the inverse square demonstrating that if the surface to be radiated receives at a distance of 1 foot 1 unit of light, at twice the distance it will only receive $\frac{1}{4}$ unit, instead of $\frac{1}{2}$, due to the spreading of the rays. Reversely, when the distance between the source of radiation and the surface to be radiated is decreased to one-half, the intensity of radiation will be four times as much as before.

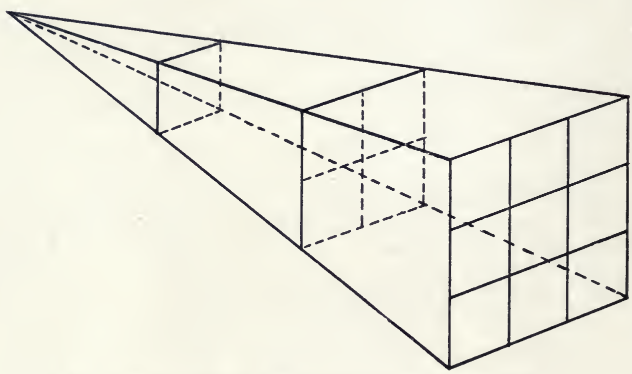

FIG. 209.—Diagram visualizing inverse square law.

The knowledge of this law must caution operators not to decrease the distance of a lamp from the body without careful calculation, in order to prevent overexposure and possible severe dermatitis. Administering treatments in the majority of cases at a fixed distance obviates the necessity of these calculations and leaves only the time as a variable factor. Because the law of inverse squares relates only to the radiation from one point, whereas therapeutic lamps produce a large amount of scattered radiation from the surface of the reflector, the calculations as to varying distance can never be made accurately.

The Angulation of Rays (Cosine Law).—Patients receive optimum radiation if the source of radiation is at right angles to the center of the area to be radiated. Figure 210 shows the increase of time necessary to compensate for the decrease of radiation due to angulation. For instance, at one-third of a right angle (30 degrees) double exposure is necessary to produce the same intensity as at 90 degrees. Within small deviation of the latter, less than 30 degrees, the small loss of radiation can be disregarded.

Penetration.—According to the law of Grotthus, formulated in 1819, only the rays which are absorbed are physiologically active. Painstaking studies in recent years have established the transmission of various forms of radiant energy through the skin.

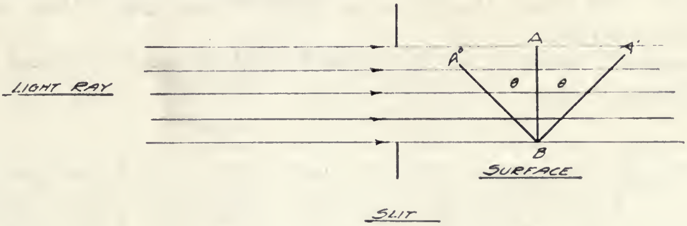

FIG. 210.—Cosine law. Intensity per unit area $= \frac{I}{AB}$.

The human skin consists of two principal layers, the outer skin or epidermis and the derma or corium. In the outer skin there is the horny layer or corneum with flat epithelial cells, the transitional layer of granulosum with flat granular cells and the rete mucosum or Malpighian layer, with the basal layer and pigment cells. In the derma there is a papillary layer or rete vasculosum containing nerve terminals and vessels and a reticular layer. Below the two layers of the skin is the subcutaneous tissue

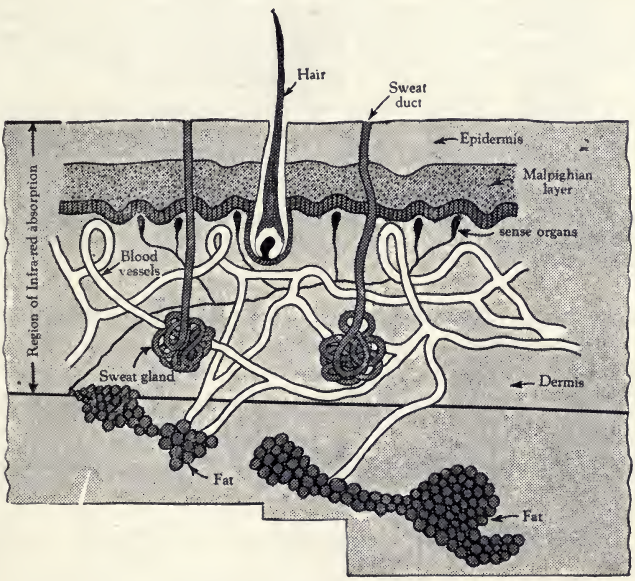

FIG. 211.—Diagrammatic structure of skin, showing areas of infrared absorption. (Courtesy of Dr. F. G. Hall.)

mainly consisting of fat. (See Fig. 211.) Radiant sources of energy penetrate through these layers differently according to their wave length and exert physiological effects in the layers where they are absorbed.

The classical table of Bachem and Reed[2] (Fig. 212) shows the penetration, absorption and relative energy transmission of radiant energy in the human skin. The summary of their findings is as follows:

Far infrared: Practically no penetration.

Near infrared: Strongly increasing absorption in upper layers, decreasing in lower layers.

Visible: Minimum absorption in stratum corneum. Most radiation absorbed in corium.

Pronounced radiation of both visible and infrared radiation reaches subcutaneous layers.

LAYER	mm.	200	250	280	300	400	550	750	1000	(1400)	mμ
		100	100	100	100	100	100	100	100	100	APPLIED
CORNEUM	.03	(100)	(81)	(85)	(66)	(20)	(13)	(22)	(29)	(56)	ABSORBED AND REFLECTED
		0	19	15	34	80	87	78	71	44	TRANSMITTED
+MALPIGHII	.05	(0)	(8)	(6)	(18)	(23)	(10)	(13)	(6)	(16)	ABSORBED
		0	11	9	16	57	77	65	65	28	TRANSMITTED
+CORIUM	2.0	(0)	(11)	(9)	(16)	(56)	(72)	(44)	(48)	(20)	ABSORBED
		0	0	0	0	1	5	21	17	8	TRANSMITTED
+SUBCUTAN.	25	(0)	(0)	(0)	(0)	(1)	(5)	(20)	(17)	(8)	ABSORBED
		0	0	0	0	0	0	1	0	0	TRANSMITTED

	EXTREME U.VIOL.	FAR ULTRA VIOLET	NEAR U.VIOL.	VISIBLE VIOL. GREEN RED	NEAR INFRA RED	FAR INF RED
GENERAL REMARKS	All absorbed by corneum. No radiation reaching germinativum	Greatest absorption in stratum corneum. Some radiation reaches corium (papillare).	Relatively large absorption in stratum Malpighii.	Minimum absorption in stratum corneum. Most radiation absorbed in corium	Strongly increasing absorption in upper layers, decreasing in lower layers.	Practically no penetration
		No radiation reaches subcutaneous layers		Pronounced radiation reaching subcutaneous layers		

Fig. 212.—Energy distribution in the layers of the skin. The number 100 designates the applied intensity. The encircled numbers represent percentages absorbed in each layer. The numbers in the narrow zones between layers represent the percentages of the original intensities transmitted through the layer above. (Bachem and Reed.)

Near ultraviolet: Relatively large absorption in stratum Malpighii.

Far ultraviolet: Greatest absorption in stratum corneum. Some radiation reaches corium (papillare).

No radiation of near ultraviolet or far ultraviolet reaches subcutaneous layers.

Extreme ultraviolet: All absorbed by corneum. No radiation reaching germinativum.

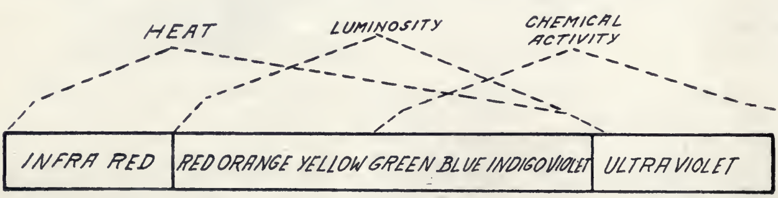

Fig. 213.—Relative extent of physical action of various portions of the light spectrum.

Comparative Physical Effects.—Although we can sharply differentiate between infrared, visible and ultraviolet radiation from a standpoint of physical measurements, on the borderline between these different wave lengths no such sharp demarcation occurs, either from the standpoint of physical or physiological effects. Table 34 and Figure 213 show the gradual merging of the physical effects of infrared (thermal), luminous and ultraviolet (chemical) radiation.

TABLE 34.—COMPARATIVE PHYSICAL EFFECTS OF RADIATION

Mainly thermal	Infrared	Strong heating effects
	Red	Fairly marked heating effects
	Yellow	Fairly marked luminous effects
Luminous	Green	Little heating Marked luminous effects Little effect on the photographic plate
	Violet	Very little heat effect Marked luminous effects Marked effects in photography
Mainly chemical	Ultraviolet	Marked effects in photography

Comparative Physiological Effects.—Radiant energy when absorbed by the tissue cells brings about a complex variety of physical, chemical and biological reactions. From the standpoint of physical therapy we may divide radiant energy into photothermal and photochemical radiations.

Photothermal radiations, comprising infrared and visible radiation, comparatively speaking, penetrate subcutaneous tissues, heat the blood, accelerate vital reactions and act instantaneously; they produce a burning sensation or immediate burn when their intensity is too great. By reflex, effects on pain and circulation in deeper structures can be elicited.

Photochemical radiations, comprising ultraviolet radiation, comparatively speaking, penetrate only to fractions of millimeters; they are absorbed by protoplasm, and this absorption results in physical and biological changes which manifest themselves only several hours after exposure. Thermal radiations are employed more often for immediate local action, while photochemical radiations are used more frequently for their subsequent effect on the general organism.

TABLE 35.—SUMMARY OF THE PHYSICAL AND BIOLOGICAL CHARACTERISTICS OF THE PRINCIPAL AREAS OF THE ELECTROMAGNETIC SPECTRUM (COBLENTZ)

Spectral region	Penetration of rays	Physiological action	Source
Far ultraviolet; 180 to 200 mμ.	Superficial, 0.1 to 0.3 mm.	Photochemical	Metals in carbon arc and spark of metals (mercury arc)
Near ultraviolet; 290 to 365 mμ.	Superficial, 0.3 to 0.5 mm.	Photochemical	Sun; metals in carbon arc and arc of metals
Visible spectrum; 390 to 760 mμ.	Superficial, 0.5 to 5 mm.	Thermal; nerve stimulation	Sun; carbon arc
Near infrared; 760 to 1500 mμ.	Deep, 10 to 30 mm.	Thermal; nerve stimulation	Sun; carbon arc; gas-filled tungsten lamp
Far infrared; 1500 to 15,000 mμ.	Superficial, 3 to 0.1 mm.	Thermal; nerve stimulation	Carbon arc; infrared (radiant heaters)

Wave lengths are expressed in millimicrons; 1 mμ. is equal to 10 Angstrom units.

The therapeutic importance of ultraviolet part of radiant energy has justly received considerable attention in recent years, while the tremendous value of the longer spectral wave lengths has not received the consideration it deserves. Visible and infrared radiation are at least equally as essential for all organic life. It has been stated that if the heat rays of the sun were to be screened off from the earth it would be surrounded by an ice crust in short order. Likewise if the sun were to cease sending us the green portion of the spectrum, on which depends the formation of chlorophyll—all important for vegetable life—all life on earth would become extinct. Just as normal organic life demands an unbroken supply of all of the rays of the solar spectrum, so in therapy in many of the results following the application of radiant energy infrared and luminous radiation play an essential rôle.

Coblentz'[3] table presents the sources and the physical and biological characteristics of the therapeutic range of radiant energy.

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CHAPTER XVI

INFRARED AND LUMINOUS RADIATION

Physical Considerations. Sources of Infrared Radiation. Heat Lamps. Infrared Generators. Electric Light Baths. Physiological Effects. Clinical Use of Local Heat Radiation. Choice Between Luminous and Non-luminous Generators. Technique of Local Radiant Heat Application. Precautions. Clinical Use of General Heat Radiation. Indications. Technique.

Physical Considerations.—Any object heated to a higher temperature than its surroundings will send out its excess of heat by radiation to the surrounding objects. An iron rod when heated first "feels" hot without showing any change in color (so-called black body radiation), then starts glowing and becomes "red-hot", and later "white-hot." At each stage of heating a variety of radiation is emitted; in the stage of low heat there occurs long-wave or far infrared radiation, invisible to the eye; at a further stage of heat the red, green and blue rays of the visible spectrum are added and at the stage of white-heat long-wave ultraviolet radiation can be demonstrated. The quality as well as the quantity of radiations emitted from any source depends not only on the physical properties of the source itself but also on the energy input, the intensity of heat generated in the radiating object.

The generally accepted classification differentiates between two groups of infrared radiations.

TABLE 36.—SOURCES OF THERAPEUTIC HEATING

Source	Form of energy	Heat transmitted
Hot-water bottle Hot compress Hot-water bath Paraffin bath Hot-air and steam bath	Long-wave infrared rays	By conduction and convection
Electric heating pad	Long-wave infrared rays	By conduction and radiation
Infrared radiator (non-luminous)	Long- and short-wave infrared rays	By radiation
Heat lamp (incandescent. bulb	Short-wave infrared rays, visible rays.	
Carbon arc lamp Sun	Short-wave infrared rays Visible rays (also ultraviolet rays)	
Long-wave diathermy	High-frequency oscillations (300-meter waves)	By conversion of oscillations
Short-wave diathermy	Very high-frequency oscillations (30- to 6-meter waves)	

(*a*) **Long-wave Infrared.**—These rays are emitted by all heated bodies, and exclusively by low temperature bodies such as hot-water bottles, electric heating pads, and dull red heaters. Their wave-lengths extend mostly from 15,000 to 120,000 Angstroms; they do not penetrate tissue deeper than 2 millimeters and are strongly absorbed in the upper layers of skin (upper 0.5 mm.).

(*b*) **Short-wave Infrared.**—These rays are emitted by all incandescent bodies such as the sun, electric arc, incandescent lamps, and especially designed high temperature infrared radiators. They comprise radiations between 7000 and 15,000 Angstroms. The employment of a special red glass filter (Danforth[5]) restricts these sources to such wave-lengths exclusively. They can penetrate through 5 to 10 mm. of skin tissue. They are therefore able to directly influence blood-vessels, lymph vessels, nerve endings and other subcutaneous tissue.

Table 36 shows the various sources of heat in treatment and their transmission. Only radiant sources of heat are discussed in this chapter. Diathermy and its relation to radiant heating has been presented in Chapter XI.

SOURCES OF INFRARED RADIATION

Sunlight is the most important natural source of infrared radiation, the proportion of infrared being over 60 per cent in the average sunlight, as compared to ultraviolet and visible light.

Artificial sources of infrared are metallic conductors which become heated by the passage of an electrical current. For low temperature heating a bare wire or carbon held in suitable non-conducting material is employed; for high temperature the oxidation of the wire must be prevented and hence the use of tungsten or carbon filaments enclosed in an evacuated or inert gas filled glass bulb. High temperature generators emit a large amount of luminous radiation. Artificial sources of infrared are divided into two groups: low temperature or non-luminous sources, or *infrared radiators* and high temperature or luminous sources or *heat lamps*. As a matter of fact in both groups infrared radiation is the chief heating factor. In actual practice the so-called non-luminous sources always attain a red glow and emit a quantity of visible red radiation, hence their designation as non-luminous is not entirely correct.

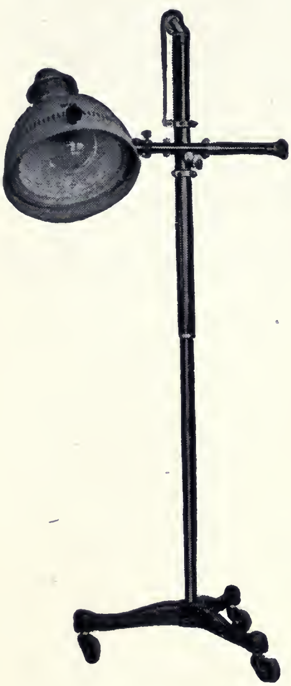

Fig. 214.—Large luminous heat generator on stand. (Courtesy of The Burdick Corporation.)

Heat lamps or incandescent filament radiators are the principal forms of luminous heat radiation. They consist of tungsten or carbon filaments, enclosed in a glass bulb mounted on the center of a concave reflector. Tungsten filament lamps are most generally used and come in different sizes, varying in wattage from 150 to 1500 watts.

The penetration of the radiation from these luminous heat generators through the skin is the same whether they are of small (150 to 250 watts) or large (1500) wattage. The principal difference between the use of the smaller and larger lamps is that the former serve for treatment of small areas, such as the face, the shoulders, hands or feet, while the large lamps are suitable to warm up larger areas of the body, such as the entire back or abdomen, both legs, etc. (Fig. 214.)

Two or more incandescent bulbs of small candle power (25 to 50 watts) mounted in semicircular containers are designated as electric light "bakers."

The term originated from the resemblance of this heating device to an oven. In contrast to the high temperatures needed for real "baking," resulting in the coagulation of albumen, the temperature rise in the skin produced by these bakers never exceeds more than about 110° F. under safe limits. Heat lamps mounted on stands are more easily moved about than some of the older type heavy bakers. Figure 215 illustrates and gives the specification of a light and inexpensive home-made baker or electric cradle suggested by the Council on Physical Therapy.

Carbon arcs are other sources of luminous heat radiation (Chapter XIX). They may produce as much as 80 per cent infrared, 15 per cent visible and a varying amount of ultraviolet, according to the type of carbons and the amperage of the lamp. The spectrum of the mercury vapor arc is weak in rays at the red end of the visible spectrum; with exception of a few strong bands in short infrared, infrared rays emitted by such lamps come mostly from the heated quartz itself by reradiation or from the warmed-up metal hood of the lamp. For comparison of these radiations study the colored frontispiece.

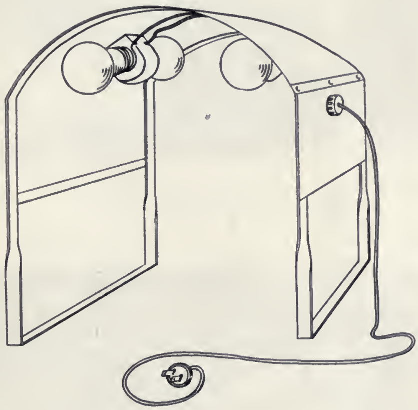

FIG. 215.—Home-made baker. (Council on Physical Therapy.)

Specifications: (*a*) frame—$\frac{1}{16}$ by $\frac{5}{8}$ inch strap iron; (*b*) reflector—highly polished tin sheeting; (*c*) 2 double receptacles, General Electric Company, catalogue 66722; 250 volts, 650 watts; (*d*) 4 60-watt mazda lamps.

The tin is riveted to the strap iron. Receptacles connected in multiple with heavy lamp cord 6 feet long. Hubble plug at the end of cord. The above baker is designed for applying heat to the legs or arms. If baker is to be used for the body, supports should be 2 or 3 inches longer.

Infrared radiators consist of a heating element which is mounted in the center of a parabolic reflector and warmed up by an electrical current to a dull red heat. The reflector should concentrate the heat rays on the surface of the body, evenly and without hot spots. In the popularly known bathroom heater, which is also an infrared generator, the wide hood reflects the rays over a wide area and the heater itself is not adjustable. The heating element consists of either a resistance wire wound or embedded on a non-conducting material (porcelain or steatite) or a rod or circular plate of resistant metal (carborundum). Similar to luminous heat generators, infrared generators are marketed in small units, drawing 50 to 300 watts of current, and large units drawing up to 1500 watts. Reflectors with suitable sockets usually allow the interchanging use of incandescent bulbs and heating elements of the same wattage. (Fig. 216.)

The difference in emission of heat lamps and infrared radiators is as follows:

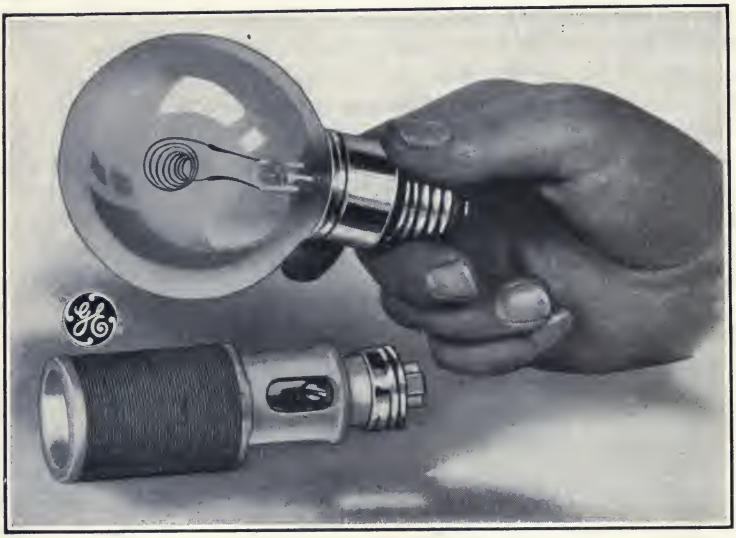

FIG. 216.—Interchangeable incandescent bulb and infrared unit. (Courtesy of the General Electric *X*-ray Corporation.)

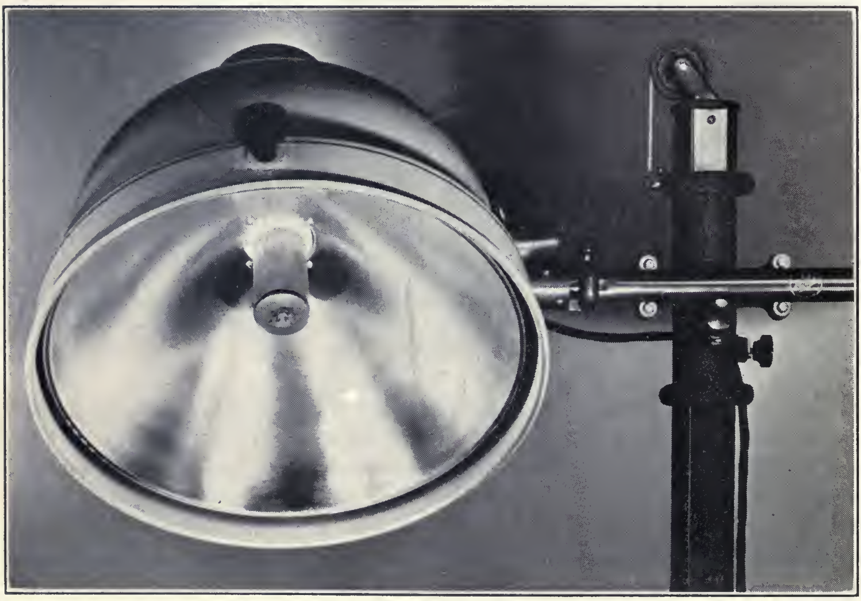

FIG. 217.—Non-metallic infrared radiator (Zoalite) in reflector. (Courtesy of The Burdick Corporation.)

Heat lamps emit a radiation of about 95 per cent infrared, 4.8 visible and 0.1 ultraviolet radiation, of which the latter is absorbed by ordinary glass. The wave length of the infrared extends from 4000 to 40,000 Angstroms, with a maximum emission from 7000 to 16,000 Angstroms. Carbon filament lamps emit more of long infrared.

Infrared radiators from a non-luminous source emit radiation throughout the entire length of the infrared spectrum to 150,000 Angstroms. The quality of radiation varies according to the surface temperature of the heating element. At the usual intensity, the emission consists principally of the shorter wave lengths, from 20,000 to 30,000 Angstroms.

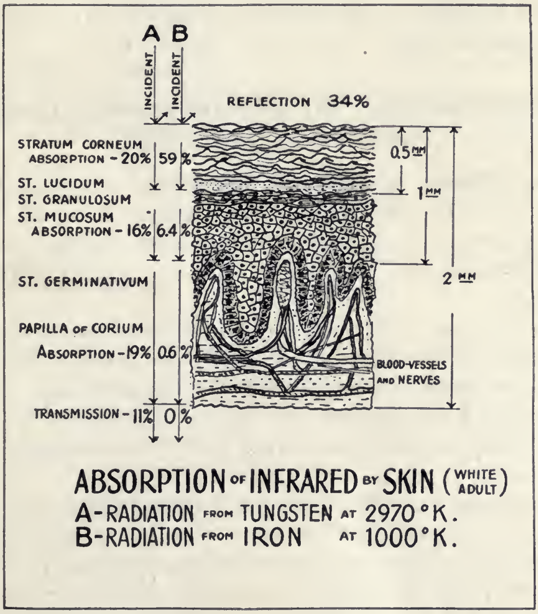

FIG. 218.—Per cent differential absorption of infrared by skin. (Courtesy of Dr. W. T. Anderson, Jr., and Archives of Physical Therapy, *X*-ray and Radium.)

The *difference in penetration* according to Anderson[1] is: A radiator operating at relatively low temperature emits long wave-lengths absorbed primarily in the stratum corneum of the skin; a generator at high temperature such as the tungsten filament lamp, emits a predominance of near infrared and visible radiation which penetrates deeply through skin layers and even into the subcutaneous layers of fat and muscles; between these two are generators at medium temperature, such as the carbon filament lamp which gives less heating effect in the stratum corneum than an iron resistor, but more than a tungsten filament; its radiation would penetrate less than that of the tungsten filament lamp. These findings are in harmony with the published investigations of Sonne,[7] Bierman[2] and Cartwright.[3] In actual practice however the various types of infrared radiators are being used almost interchangeably because much of the effect of infrared radiation is due to reflex effect, for which no deep penetration is necessary.

Electric Light Baths.—Electric light baths of the upright type consist of a metal or wooden cabinet fitted with a number of incandescent lamps arranged along the inner sides. The lamps are, as a rule, 80-watt bulbs having a carbon or tungsten filament controlled by a number of switches, so that some or all of them may be turned on. The cabinet should be partially open at the top and should have an air vent, preferably at the center of the floor. A thermometer emerging from the top registers the temperature inside.

When general light baths are desired for bed-ridden patients and no light cabinet is available, a fairly efficient substitution can be made by a string of carbon filament lamps draped over a bed cradle and covered by a bed sheet.

Electric light cabinets of the reclining type for fever therapy have been described in Chapter XII.

PHYSIOLOGICAL EFFECTS OF INFRARED AND LUMINOUS RADIATION

Physiological Effects of Infrared Radiation.—Heating the superficial tissues of the body by infrared radiation exerts local as well as general effects; these effects vary according to the extent of the area exposed and the intensity of radiation. There is often an interplay between local and general action.

Table 26 in Chapter XI by Bazett shows the local and general effects of radiant heating on the circulation, the blood, the lymph, on the tissues, on respiration, on the urine and sweat and on infections.

From the clinical standpoint two main local effects of heat radiation are the stimulation of local circulation and the stimulation of the nerve endings of the skin.

1. **Effect on Circulation.**—Within a few minutes after exposure to radiant heating the skin turns red and feels hot; there is no latent period as with ultraviolet radiation. The resulting erythema appears in the form of red spots or a network of red lines; it persists depending on the length of exposure from ten minutes up to one hour. This erythema is due to the stimulation of the vasomotor mechanism and manifests itself by active vasodilatation of the capillaries and subsequent increase of arterial and venous circulation. As already stated in Chapter XI, there exists an inherent tone in the capillaries which causes vasoconstriction and the application of heat produces a release of vasodilator substance. Upon the absorption of the vasodilator substance more capillaries become active and as a result a greater blood supply to the part occurs.

The erythema caused by dilatation of the capillaries in the corium of the skin occurs after exposure to any form of infrared radiation; in addition, luminous sources containing a large amount of the more penetrating infrared cause a marked stimulation of the sweat glands located in the subcutaneous tissue; as a result, drops of perspiration soon appear in the area under exposure. This effect becomes especially evident when large areas of the skin are exposed to general heat radiation from incandescent sources, as in an electric light cabinet.

Repeated exposure to infrared radiation may lead to permanent *pigmentation* which, in contrast to the homogeneous tanning following ultraviolet radiation, is always mottled, like the surface of marble. The mottled appearance of the skin in regions habitually exposed to heat radiation is well known.

Table 37 shows a comparison of infrared and ultraviolet radiation, with special reference to erythema production, pigmentation and tolerance.

Excess amount of infrared radiation or special sensitivity thereto results in wheal formation, local edema and eventually in blistering. Careless exposure may cause deep sloughing not only in the skin but also in adjacent subcutaneous and fibrous structures.

TABLE 37.—COMPARISON OF INFRARED AND ULTRAVIOLET RAYS

Radiation		Infrared		Ultraviolet	
		Long:	Short:	Long:	Short:
Wave length		120,000 to 16,000 A°	15,000 to 7000 A°	4000 to 2900 A°	2900 to 1800 A°
Penetration		0.1 to 3 mm.	10 to 30 mm.	0.3 to 0.5 mm.	0.1 to 0.3 mm.
Erythema	Development	Immediately		After hours	
	Appearance	Darker red, spots or network		Lighter red, sharply bordered	
	Duration	Less than one hour		Hours and days	
Pigmentation		Mottled		Homogeneous (tanning)	
Tolerance		Develops occasionally		Increases constantly	

TABLE 38.—MAXIMUM TOLERANCE SURFACE TEMPERATURES UNDER RADIANT HEATING (SONNE)

Radiation	Surface temperature	Under surface temperature
Short infrared and visible	110.8° F.	117.8° F.
Long infrared	113.9° F.	107.0° F.

2. **Effect on Nerve Endings of the Skin.**—Mild heating results in sedation or relief of pain while strong heat stimuli cause marked counterirritation. The mechanism of counterirritation may be explained by the desensitization of superficial sensory nerves or by a considerable increase of the stimuli which pass over them: the effect is that of relief of local painful stimuli as well as of those originating from deeper parts and possessing the same nerve center as the area of the skin under the influence of heat. Aside from these two groups of effects explainable by the local thermal effects on tissues, there is no evidence of any specific action of infrared rays, neither is there any evidence of antagonism between these rays and visible or ultraviolet rays in regard to biological effect. There is no scientific basis for giving treatment with a dark infrared source for a few minutes, as if it were comparable to a powerful source of ultraviolet rays (Coblentz).

General Effects.—Every local application of heat brings about a certain amount of general heating. The local excess heat is taken up by the blood stream and carried into the general circulation. The temperature control mechanism of the body will immediately throw off the additional heat by mild perspiration. Intense general heat application from large heating units ("body bakers" or high-wattage lamps or heat cabinets) stimulates the heat-regulating mechanism to full activity in its endeavor to make the output of heat equal that of the increased input.

The generally recognized effects of mild general body heating are: (1) Increased heat elimination and profuse perspiration; (2) increased circulation, a rise of the pulse-rate in the ratio of about 10 beats for each degree Fahrenheit, just as it does in fever; (3) a lowering of blood-pressure (in contrast to the effects of cold); (4) increased respiration; (5) increased elimination through the kidneys. There is a loss of water, salt, urea and other nitrogenous substances, with a relative excess of alkali remaining in the blood and in the tissues, while there is also a temporary loss of body weight. General nervous sensibility is usually markedly lessened.

The effects of prolonged and intense heat application in the form of fever therapy have been discussed in Chapter XII.

Physiological Effects of Visible Radiation.—Visible radiation is present in all radiation from incandescent sources, carbon arc and mercury vapor lamps, but its total quantity is relatively small (5 to 15 per cent); the thermal effects of radiation are attributable principally to the near (short) infrared rays. The generally accepted conception of the physics of luminous radiation in relation to the tissues is as follows: 11 per cent of the visible radiation from a tungsten filament lamp is absorbed by the glass bulb and 33 per cent is reflected by the skin; all of the remainder is absorbed by the superficial layers of the skin but does not penetrate as deeply as the short infrared.

Tyndall demonstrated by classical experiments that it is possible to convert light into heat and *vice versa*. He passed a beam of electric light through water to absorb the heat rays and then by passing the resultant rays through a lens of ice, he set fire to black paper, and ignited gun cotton on the other side of the ice, showing that this result was brought about by the light rays exclusively.

Other physiological effects than those due to heat are attributed to luminous rays, but they are doubtful. The theory has been advanced that luminous rays mitigate the burn produced by ultraviolet rays by increasing the supply of lymph and blood, and so wash away the product of tissue damage produced by the ultraviolet rays. The curative effects of light on wounds, sinuses, etc., has been attributed to the stimulation by the visible rays.

The totality of the visible spectrum may be broken up by prisms or suitable filters in different wave lengths representing different colors:

Table 39.—Wave Lengths of Visible Spectrum

Violet	4000 to 4500 A.U.
Blue	4500 to 4900 A.U.
Green	4900 to 5500 A.U.
Yellow	5500 to 5900 A.U.
Orange	5900 to 6300 A.U.
Red	6300 to 7800 A.U.

It has been claimed that by separating the visible white into its component parts, red, yellow, blue, etc., these colored bands can be utilized for specific therapeutic purposes, such as blue for sedation and red for stimulation. There is little evidence so far to substantiate these claims, chiefly because the filter arrangements for the production of such pure blue, red or other light, if effective physically, usually produce an inert radiation by keeping off the bulk of the electromagnetic energy. Different colors of light undoubtedly exert a certain amount of psychological effect irrespective of the amount of effective radiation.

CLINICAL USE OF LOCAL HEAT RADIATION

Luminous and non-luminous sources of heat radiation produce marked hyperemia, tissue relaxation and relief of pain in an irradiated area. These effects will assist in the resorption of products of trauma and inflammatory reaction and aid the natural forces of defense and restoration.

The advantage of heat radiation over methods of conductive heating (hot-water bottles, poultices, etc.) is: (1) that its action extends to a greater depth; (2) that there is no pressure over the parts; and (3) that the parts may be kept under constant observation without difficulty. Thus signs of undue heating can be discovered immediately. Kellogg pointed out some time ago that if the surface of the skin be kept cool by fans, much more heat can be applied for the relief of deep-seated pain.

FIG. 219.—Application from localizing infrared radiator. (Courtesy of The Burdick Corporation.)

Infrared radiation, on account of its comparative simplicity and safety of application, is preferable to diathermy in many conditions when efficient heating of structures not too deeply situated is desirable. Figure 212, showing the penetration of human tissues by the various wave lengths of therapeutic radiation, demonstrates that near infrared penetrates the entire thickness of the skin, part of the subcutaneous tissue, superficial strata of muscles and accessibly located tendons and bones.

The *indications* for the clinical use of infrared heating overlap those from conductive and conversive sources. The choice of method depends partly on clinical experience and partly on the considerations as to which method is more easily available. No hard and fast rule exists which would make the selection of a particular form of heating imperative in a given condition. With heat radiation applied daily to hospitalized patients with traumatic and arthritic conditions the author has produced results fully comparable to diathermy treatments applied every other day to ambulatory patients with the same conditions.

The principal indications for radiant heating are as follows:

1. Subacute and chronic traumatic and inflammatory conditions in locations accessible to external heating. Contusions and muscle strains, traumatic synovitis and tenosynovitis, sprains, dislocations and fractures.

2. Various forms of arthritis and rheumatoid conditions, neuritis and neuralgia; in acute forms, mild infrared radiation may be the only means of relieving pain without medication. In these conditions the advantage over poulticing and hot-water bottles is especially evident because of the avoidance of pressure.

3. Acute, subacute and chronic catarrhal conditions of the mucous membranes in accessible location: conjunctivitis, coryza, sinusitis, otitis media (non-suppurative form), bronchitis. In incipient cases early and efficient use of radiant heat may abort an otherwise prolonged attack.

4. Circulatory disturbances of the extremities (thrombo-angiitis obliterans, thrombophlebitis, endarteritis obliterans, Raynaud's disease and erythromelalgia). Great caution is always needed and thermostatically controlled heating (kept around 97° F.) is safer.

5. Infections of the skin, folliculitis, furunculosis and even extended abscess formation in the skin. Efficient infrared application may in minor cases reduce surgical intervention in form of incision and drainage to a minimum or make it unnecessary. Infrared radiation is convenient to keep up the required temperature in hot antiseptic dressings in infections and cellulitis. It offers the advantage that the heat is constant, is applied without pressure and there is no carrying of infection as may be the case with water; furthermore, the patient need not be disturbed and does not need so much attention.

6. Radiant heating may be applied as a preliminary to other physical measures. Massage, voluntary and passive exercise and passive muscular exercise by low-frequency currents should always be preceded by some form of heating; the relaxation and preliminary warming making the tissues supple for manipulation or exercise. Radiant heat is most efficient for this purpose. Preceding the application of the galvanic current or of long-wave diathermy with a few minutes' exposure to radiant heat will improve skin conductivity by inducing hyperemia and a slight perspiration. A more satisfactory general reaction to ultraviolet irradiation from mercury vapor lamps may also be produced by preliminary general radiant heat application.

Choice Between Luminous and Non-luminous Radiators.—While the quality and penetrating power of the radiation from these two types of generators differ considerably, there are, as yet, no reliable clinical data to indicate any preference in routine application of radiant heat therapy. It has been stated that the difference between the output of high temperature (luminous) and low-temperature (non-luminous) radiators is the predominance of the short, more penetrating infrared rays in the first group. More of the long infrared (non-penetrating) radiation from non-luminous radiators is absorbed by the top layers of the skin, and for this reason such generators feel hotter from the same distance than luminous heat generators of the same wattage and with the same type of reflector.

Individual preferences of patients sometimes favor one source over the other. Patients at times feel bothered by a bright light whereas the dull glow of infrared feels more comfortable. This is especially the case when the face is treated and also in feverish, restless children. There are also some indications that in acute painful conditions radiation from a non-luminous source often feels more soothing. In the author's clinical experience luminous sources of radiation furnish more penetrating heating and should therefore, be preferable for treatment of traumatic conditions affecting deeper parts. Luminous heating has also proven more effective in conditions where more rapid perspiration is desirable.

Technique of Local Radiant Heat Application.—The patient should be placed in a comfortable, relaxed position and the radiation from the generator is directed over the part to be treated, at a distance from which it feels comfortable. The distance will average from 2 to 3 feet, according to the sensitivity of the parts, the intensity of the radiation and the type of reflector.

Exposure is continued for from ten to fifteen minutes when the object is merely to warm up the parts preliminary to some form of treatment; for one-half to one hour, if heat radiation is the main part of the treatment. The routine employment of a time clock for exact measurement of the time of treatment serves as a protection for patient and physician. Too long exposure, if not too intense, usually does not produce harmful effects in local treatments; in some acute painful conditions, such as brachial neuritis, it may be helpful to apply infrared radiation for as long as one to two hours at a time. Physicians and technicians often err by using heat radiation for too short a period to be effective.

Precautions.—If at any time during treatment the patient complains of unpleasant burning over the entire area or over one spot, the heat lamp should be moved a few inches farther away; this process may have to be repeated until the patient feels entirely comfortable. Patients who receive treatment for the first time often think that a severe burning sensation is part of the treatment; such indiscreet patients may become blistered and, therefore, special watchfulness is always indicated when treatment is applied for the first time.

Anesthetic areas in patients with peripheral nerve injuries and over scars are especially prone to blister, so that in these cases heat generators should be kept at a distance of at least one and half or more of the usual space and even then one should always look out for signs of possible blistering.

CLINICAL USE OF GENERAL HEAT RADIATION

Indications.—The effects of mild systemic heating on metabolism, on the circulation and as a sedative led to its clinical employment as a valuable adjunct to general therapeutic measures in the following conditions:

Chronic arthritis and rheumatoid conditions, especially in the well nourished, robust type of patient; chronic nephritis; psychoneuroses—in combination with hydriatic measures—and in agitated and maniacal mental states in coöperative patients; toxic multiple neuritis, obesity, early arteriosclerosis.

In chilling after exposure a large heat lamp is a most efficient emergency measure. It is much safer than hot-water bottles and should therefore be available in all accident wards.

The indications and technique of hyperpyrexia by general heat radiation have been presented in Chapter XII.

Technique.—The technique of general heating by large wattage heat lamps or infrared radiators is the same as in local heating save for the larger surface exposed. Applications from fifteen minutes or one-half hour at a distance of comfortable toleration are administered.

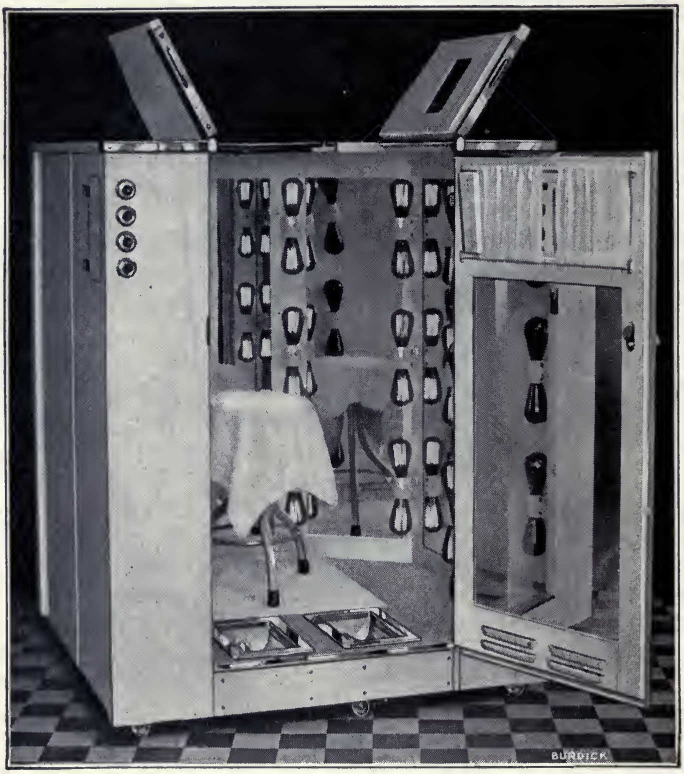

Fig. 220.—Large electric light cabinet. (Courtesy of The Burdick Corporation.)

In the use of electric light cabinets before the patient enters the cabinet its lights should be turned on to raise the inside temperature. The patient comes covered by a large sheet or thin bathgown; the covering is then discarded with the patient seated on a low stool. The top of the cabinet is closed so that the head remains outside. The forehead is covered by a cold-water compress; this prevents headache and too much flushing of the face. If the purpose of the bath is to promote elimination the patient may freely drink during the treatment in order to encourage perspiration. The patient should never be left alone, and if at any time he feels faint or the pulse-rate rises above 100 or becomes irregular the treatment must be stopped. There are cabinets in which patients can recline, such as the newer fever cabinets and they are quite convenient for mild general heating.

In the light bath thus administered, as a rule, an immediate hyperemia of the skin occurs; there is also a gradual onset of perspiration. The pulse, temperature and respiration rise in a degree varying with the length of the bath and the individual reaction. As a result all metabolic and vital activities are quickened.

The duration of the light bath should depend on the desired effect. If general tonic action is desired the exposure should be brief, five to eight minutes, just to the point of beginning good perspiration. For marked elimination and derivative action, eight to fifteen minutes' exposure should be given.

After the bath the patient should receive a tepid shower or a contrast, hot and cold (Scotch) douche, according to the stimulation desired; or at least a good rub-down should be given with warm towels or with alcohol. A dry garment is then put on and the patient allowed to rest for twenty to forty minutes. No patient may leave after a light bath until he has thoroughly cooled off. Baths for tonic purposes may be administered every day or every other day, those for elimination about twice a week.

In *bedridden patients* general light baths may be administered by suitable electric light bakers. Pemberton[6] describes the technique as follows:

"The patient is enveloped snugly in a blanket, the electric light 'baker' is placed over the body, with the exception of the head, and the various apertures of the appliance through which heat might escape are covered with several blankets, as is indeed the whole apparatus. The number of electric lights to be used must be determined by experience, and the current should be controlled by a switch on the outside of the 'baker.' A thermometer should be placed above the body of the patient but under the covering blanket and, in order that the temperature may be easily and frequently determined, it should be fastened to a cane or yardstick. A common mistake in this connection is to place the thermometer above the blanket exposed to the full influence of the lights, at which point it does not indicate properly the temperature to which the subject is actually exposed, and the process as a whole may be, therefore, unduly curtailed. The usual practice is to begin by elevating the temperature within the apparatus to 49° C. (120° F.) and to maintain this temperature for twenty minutes, after which the lights are turned off and the patient is allowed to remain wrapped in the blanket until he has cooled down to normal. The duration and temperature of the process must vary with cirumstances and it is always well, except in emergencies, to err on the conservative side, especially at the outset. The body temperature may rise from 0.5° to 1.5° F., and it is customary to place an ice-cap on the head and to administer water. Too much water, however, may prevent the degree of hyperpyrexia necessary to determine sweating, and it is also obvious that, in the presence of edema, ingestion of water may partly defeat the purpose in mind. Usually one glass of cool water during the 'bake' is ample. It is sometimes advisable to include only part of the body, especially the loins, in the 'bake,' leaving the chest outside. Pulmonary edema has resulted from careless or undue application in severe nephritis.

"Considerable prostration may occasionally follow the general procedure described; and, furthermore, although the effect of any one 'bake' may be inappreciable, the effect of many treatments is sometimes cumulative."

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CHAPTER XVII

ULTRAVIOLET RADIATION—PHYSICS AND EFFECTS

Generation. Classification. Physical Properties. Physiological Effects. Erythema Production. Pigmentation. Antirachitic Effect. Bactericidal Effect. Effects on Blood. Effects on Metabolism. Clinical Uses. Contraindications. Photosensitization.

Generation.—Very hot bodies and ionized gases emit ultraviolet rays. In order to obtain an appreciable amount of ultraviolet radiation it is necessary to heat the radiating substance to a temperature of 3000° C. (5400° F.) or higher (Coblentz[4]). The chief natural source of ultraviolet radiation is the sun. The sources of artificial ultraviolet radiation are chiefly electric arcs between electrodes of metals, of carbon and of mercury in quartz. Radiations from artificial sources represent but approximations to sunlight, and no two are alike in respect to the spectrum distribution of the energy they emit.

Classification.—The range of radiant energy designated as ultraviolet extends from 3900 to 1800 Angstroms and is divided into: (1) "Near ultraviolet" radiation, which is continuous to the luminous rays, and consists of comparatively long rays, extending to 2900 Angstroms; (2) the "far ultraviolet" radiation, consisting of comparatively short rays, extending from 2900 to 1800 Angstroms. The sun's spectrum contains none of these short rays.

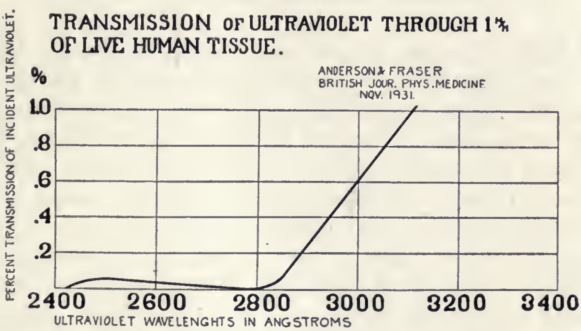

Fig. 221.—Curve of ultraviolet transmission through human tissue.

Physical Properties.—Ultraviolet rays penetrate to a very limited extent through bodies. Quartz permits their passage up to 1800 Angstroms, hence the employment of quartz for the construction of burners and filters. Air permits passage up to 1850 Angstroms, but impurities in the air, dust and smoke will filter out even more especially at low levels. Ordinary window glass permits only the passage of rays longer than 3200 Angstroms.

The human skin arrests all ultraviolet radiation, and beyond the depth of 2 mm. only the rays longer than 4500 Angstroms can penetrate. Paper and even the thinnest underwear arrest most of the radiation.

Ultraviolet radiation brings about fluorescence of many substances. The surface of a roentgen-ray screen becomes phosphorescent after exposure to ultraviolet rays. They exert photochemical effects in decomposing silver salts and in discoloring vegetable colors, and photoelectric effects causing emission of electrons from negatively charged metals. If a negatively charged electroscope is placed in the path of certain ultraviolet rays its leaves collapse, showing the loss of its electric charge. The presence of ultraviolet rays in any light can be proved by this simple test. The formation of ozone from the oxygen of the air by photosynthesis is also attributed to the action of ultraviolet rays.

PHYSIOLOGICAL EFFECTS OF ULTRAVIOLET RADIATION

The variety of effects of ultraviolet radiation on substances outside of the human organism points to the possibility of effects of much more complex nature on the intricate tissues in the living organism. Laurens[13] says that the fundamental principles of the biophysics and physiology of radiation are still unsolved, and the real action of radiation on the living cell is unknown.

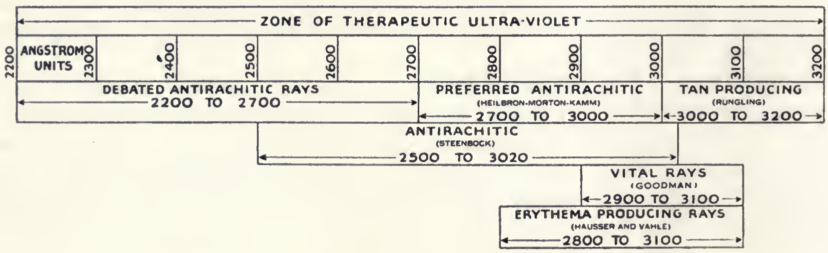

FIG. 222.—Zone of therapeutic ultraviolet radiation.

Ultraviolet light does not act as a unit biologically, for various zones of the large ultraviolet field cause different biological effects. The very long wave lengths (from about 3200 to 3100 A.U.) penetrate deeper into the skin, but exert little biological action; the very short rays (below 2300 A.U.) have practically no penetration and exert also very little biological effects; it is in the intervening zone from about 3100 to 2500 Angstroms where most of the biological reactions occur. Some of these zones or bands have very distinct effects and some generators are being developed which produce such so-called "monochromatic" radiation.

The effects of ultraviolet radiation from a biological standpoint have been classified as photochemical ones occurring in the skin and biological ones occurring in the blood and in the metabolism. The photochemical effect ends with the production of dermatitis and the activation of substances in the skin and possibly in the blood, while the biological, the effect on metabolism, growth, circulation, etc., lasts for some time (Laurens[13]).

From the therapeutic standpoint the physiological action of ultraviolet may be discussed under the headings of erythema production, pigmentation, bactericidal effects, antirachitic effects and, finally, effects on the blood and metabolism.

1. **Erythema Production.**—Radiant energy between 3200 and 2400 Angstroms produces local erythema of the skin which develops in one to eight hours, depending on the sensitivity of the subject and the intensity of the radiation. Because this effect appears most rapidly and is among the

easiest to detect, it has come to be considered as a sign of an effective light source or as a measure of an effective dose of radiation.

Degrees of Erythema.—Erythema of the skin is a true inflammatory reaction and can be described according to its intensity, as of four different degrees. Each of these degrees is associated with the conception of a definite dosage of ultraviolet.

(*a*) First degree erythema or tonic dose: A reaction so slight that it is scarcely noticed by the patient. The skin reddening is very faint, occurs after a latent period of some hours, usually subsides within one or two days and without leaving any trace whatsoever. Should be administered on the entire body or largest possible area. A reaction just below the first degree erythema is variously called the minimum perceptible erythema or a suberythemal dose.

(*b*) Second degree erythema: A mild sunburn reaction. The reddening is plainly visible and is followed on subsidence by slight desquamation. Subsides in about three days and may leave some pigmentation.

(*c*) Third degree erythema, also designated as a counterirritant dose: An intense reaction similar to severe sunburn. The reddening is intense and there is also a slight edema. It is followed by peeling of the skin and takes about a week to subside, leaving pigmentation. This intense sunburn is essentially employed as a local reaction.

(*d*) Fourth degree erythema, also designated as a bactericidal or destructive dose: An intense reddening, supervening after a short latent period (about two hours) and increasing until exudation and blistering results; persists for many days and leaves deep pigmentation in its wake. Only administered on small areas, at contact, or short distance.

Histological Changes.—The histological changes associated with erythema production are as follows: The capillary vessels of the irradiated area are filled with red blood cells; there is also marked leukocytosis in the irradiated area; this reaction is not confined to the irradiated surface, but extends deeply in the tissues. Following intense irradiation there is serofibrinous and often hemorrhagic exudation and in a further stage thrombi form in the vessels of the arteries and degeneration and necrosis of the skin as well as of the deeper parts may follow. With the routine mild erythema doses, however, the usual reaction is a dilatation of the superficial vessels with some increase in blood flow; after a duration of the hyperemia for a varying period there is full restoration to normal.

Difference in Erythema Effect of Certain Wave-lengths.—No perceptible erythemal effect is produced by wave lengths below 2400 Angstroms and above 3200 Angstroms. The almost immediate reddening of the skin after irradiation by a strong source of mixed radiation such as the sun or a heat lamp or carbon arc lamp is due to radiant heat rays. Such radiation is not restricted to the irradiated parts of the skin, has a mottled appearance and disappears soon after irradiation has stopped. (Table 37.)

Within the range of wave lengths with erythemal action there are two maximal areas of erythemal effectiveness, as shown in Figure 223. One is at about 3000 Angstroms, the other at about 2500 Angstroms. These two maxima have not the same value in a photobiological sense. Erythema produced by radiation at 3000 Angstroms is followed, according to its intensity, by strong pigmentation and painful blistering—a real sunburn—

while erythema produced by radiation around 2500 Angstroms leaves scarcely any, or at most only an inconsiderable pigmentation.

Biological Explanation of Erythema.—Research work on the biophysical response of the skin to radiation at different wave lengths has offered an explanation of the diverse erythema and pigmentation action of the two maxima of the erythema curve.

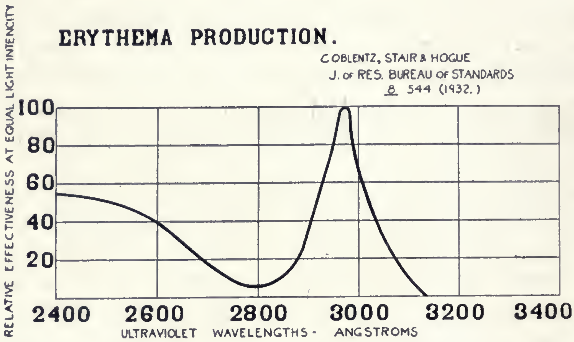

Fig. 223.—Curve of erythemal effectiveness of radiant energy.

The erythema production of the skin is a true inflammatory reaction and is in degree similar to those described by Lewis[15] as a result of mechanical, thermal or electrical stimuli. Following irradiation the walls of skin vessels become permeable, their cells activated, certain substances in the skin pass from these cells into the blood. Among the substances affected is the H-substance of Lewis, histidine, which undergoes a photochemical change into histamine. Histamine produces a vivid erythema when introduced into the skin even in minimal amounts. Only wave lengths under 2700 Angstroms bring about this histidine-histamine change and hence the vivid erythemal action of these shorter wave lengths without pigmentation. On the other hand, according to Memmesheimer[17] tyrosine and other amino-acids are also activated in the skin by irradiation; tyrosine is the substance which produces pigment which is deposited in the horny layers of the epidermis. Wave lengths of 3000 Angstroms bring about this change and hence the tanning effect following erythemal doses of the longer ultraviolet wave lengths. The erythemal effect of these wave lengths is explained by Frankenburger[9] by the assumption of an incursion of minute amounts of histamine into the outer layers in consequence of cell destruction through the longer waved rays there absorbed.

Erythema Reaction as a Measure of Effectiveness of Ultraviolet Radiation.—While the erythema is by no means the most important biological effect of ultraviolet radiation it serves at present as the only available practical and reliable basis for judging clinically as to the effectiveness of ultraviolet radiation. The Council on Physical Therapy[5] has adopted this reaction for the measure of efficiency of ultraviolet generators for the following reasons:

(*a*) The erythemic response is in common use as an indicator of skin tolerance and of the amount of ultraviolet radiation that can be applied at one time; and, as long as the present-day types of ultraviolet generators are used, the erythemic test will be necessary to prevent injury from burns.

(*b*) It is practically the only physiological reaction to ultraviolet rays that is established with a relatively high degree of accuracy, permitting a calculation of the approximate time of exposure from a simple physical measurement of the ultraviolet radiant flux emitted by the lamp.

(*c*) It is a simple and practicable means of preventing severe burns when using powerful sources of ultraviolet radiation.

(*d*) It is an efficient safeguard against the fraudulent sale of lamps that emit little or no radiation of wave lengths shorter than about 3130 Angstroms, generally accepted as having a specific therapeutic value in preventing rickets.

The specifications for minimum intensity of ultraviolet generators based on this test will be presented in Chapter XVIII.

2. **Pigmentation.**—Repeated irradiation with erythema doses between 2800 and 3000 Angstroms causes pigmentation which consists of a deposit of granules of the pigment melanin in the basal cells of the epidermis. Pigmentation and erythema are associated only in the longer wave lengths, for as already stated, the erythema producing wave lengths around 2500 are not followed by late pigmentation. It is also well known that repeated stimulation by other agents such as repeated friction and other mechanical irritation may also bring about deposition of pigment.

The rôle of pigmentation is still a matter of controversy. Rollier[21] advanced the theory that the short, lethal waves are transformed by the fluorescent action of pigment into long waves, thereby increasing the depth of penetration and the intensity of reaction. According to a slightly different point of view, pigment favors the penetration of energy by changing a white reflective surface into a dark absorbing one and the greater the pigmentation of the subjects the more marked is the change in blood reaction. Bernhard[2] pointed out that dark skin warms much more quickly and thoroughly than does fair skin. Aitken[1] on the basis of an experimental study concludes that pigment is produced in greatest abundance under the influence of luminous rays and serves to protect deeper parts against these rays.

Laurens[14] considers pigment formation and healing, or benefit from the energy, as independent, coördinate phenomena proceeding simultaneously in the same direction. Since the horny layer is a more important protector against over-irradiation by shorter ultraviolet rays than is the skin pigment, there is left but one outstanding significant connection between radiation and pigment, namely, as an indicator of the action of the radiant energy, its intensity being, to a certain extent, proportional to the amount of action. But it is also very dependent upon individual factors such as race, constitution and body function. Pigment formation is an indicator of the wished-for action and can be used as a measuring rod for treatment.

3. **Antirachitic Effect.**—(Activation of vitamin D.) Ultraviolet radiation between 2800 and 3200 Angstroms causes in the skin an activation of cholesterol, accompanied by ergosterol, and in turn about 60 per cent of the latter substance is converted into vitamin D. The mechanism of this transformation is a complicated biochemical process. Vitamin D is an essential necessity of everyday life; it promotes normal anabolism of calcium and retention of phosphorus. Following ultraviolet irradiation calcium and phosphorus are absorbed to a greater extent and calcium deficiency in a growing child, resulting in rickets, is overcome.

Ultraviolet irradiation of a lactating woman increases to some extent the quantity and antirachitic potency of the milk. It also has been found possible to render cow's milk antirachitic by direct irradiation. Milk is the only common food considered for acceptance by the Council on Foods and Nutrition when fortified with vitamin D. One of the methods used to impart antirachitic properties to vitamin D milk is irradiation with ultraviolet rays shorter than 3130 Angstroms.

The action of ultraviolet and cod-liver oil on calcium and phosphorus retention are interchangeable; however, according to Laurens[13] cod-liver oil has much less general beneficial effect than ultraviolet rays and the latter produce more general improvement in the activity, muscle tone and contentment of rachitic infants.

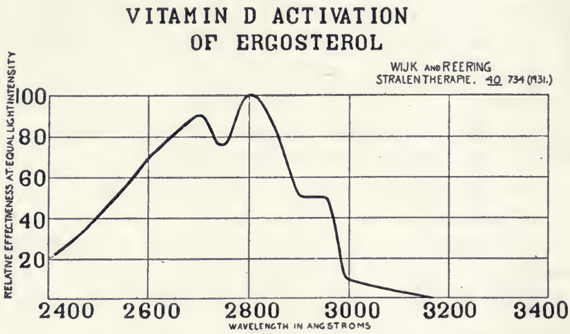

FIG. 224.—Curve of ultraviolet spectrum effective in activation of ergosterol.

4. **Bactericidal Effect.**—Investigation of the lethal action of different wave lengths of ultraviolet on bacteria smeared on agar plates showed that the maximum bactericidal effect lies in a zone midway between 2000 and 3000 Angstroms. Figure 225 shows a curve characteristic of the bactericidal effect on B. coli with a maximum around 2500. Bactericidal effects on the tissues of the human body by ultraviolet are limited by the penetration of ultraviolet restricted to the uppermost layer of the skin—a depth of 2 mm. Most of the standard lamps emit only a limited amount of the bactericidal range and because of the preponderance of the other intense erythema producing rays the effective use of the germicidal band is further limited. When Finsen first treated tuberculosis of the skin successfully with prolonged administration of "cold" ultraviolet (the heat rays of carbon arc radiation were eliminated by a water filter) he was of the opinion that the result was due to a bactericidal action on tuberculosis germs whereas we know now that in this instance the profound local inflammatory reaction is the principal curative factor.

In recent years ultraviolet lamps have been constructed emitting principally bactericidal radiation and extensive laboratory and clinical studies have been made as to the various aspects of bactericidal radiation. As a result ultraviolet ray sanitation has been introduced on a large scale (see Chapter XIX) and some of these lamps have also been employed for bactericidal effects on the skin surface.

5. **Effects on Blood.**—Definite changes are produced by ultraviolet radiation on the blood and blood producing organs, most likely by indirect

effects *via* the skin and possibly *via* the sympathetic nervous system. There is some conflict in the findings reported in the extensive literature and this is explainable, as Laurens[13] points out, by the fact that observations reported by various clinicians were made under the most varied conditions, with a variety of light sources and on the healthy, the sick, on children and adults, as well as on animals.

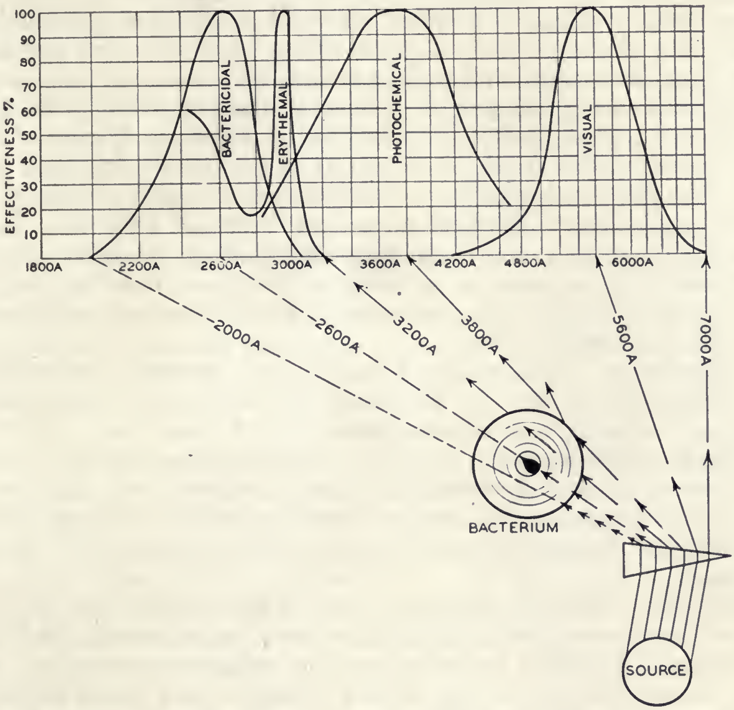

FIG. 225.—Curves of relative effectiveness of ultraviolet spectrum and indication of bactericidal selectivity at 2650 A°. (General Electric Co., Nela Park Division.)

TABLE 40.—EFFECTS OF ULTRAVIOLET IN SECONDARY ANEMIA[12]

Group	No. of cases	Averages: Before	Averages: After	Increase
Hemoglobin:				
Controls	14	64.0	64.5	0.5
Filtered irradiation	19	65.0	76.1	11.1
Complete irradiation	21	64.5	78.0	13.5
Red blood cells:				
Controls	14	3,023,000	3,128,000	105,000
Filtered irradiation	19	3,056,000	3,675,000	619,000
Complete irradiation	21	3,132,000	3,723,000	591,000
White blood cells:				
Controls	14	8750	9100	350
Filtered irradiation	19	7950	8600	750
Complete irradiation	21	7420	8180	760

Effects of ultraviolet from hot quartz mercury arc on the blood picture of three groups of hospitalized patients with secondary anemia. Fourteen controls with the same average anemia received no irradiation, 19 patients were irradiated through a Corex D filter and 21 received the complete spectrum.

Radiation with massive exposures from carbon and mercury arcs has increased consistently red blood cells and reticulocytes. In animal experimentation, blood regeneration in anemic conditions takes place more rapidly under irradiation than in its absence. In human anemias the fairly consistent increase of red cells and the hemoglobin content under ultraviolet radiation were demonstrated by the author[12] in a study of hospitalized patients and controls (Table 40). As a rule acceleration appears to be greater if the complete spectrum is used instead of only the longer ultraviolet range through a Corex D filter. The increase of white cells was not quite so definite. Rebbeck[20] showed that irradiation of the blood and its reinjection into the patient raised the blood cell count and hemoglobin. The mechanism of this effect is not quite clear.

Other authors report a definite increase of white blood cells with leukocytosis and lymphocytosis and an increase of polymorphic cells. Among other reported effects on the blood are: (1) a rise in its bactericidal power due to the erythema producing rays and there is probably associated with this factor an increase of resistance to some forms of infections. (2) An increase in the calcium and phosphorus content of the blood serum due in all probability to an increased absorption of calcium from the intestines. (3) Increased alkalinity of the blood under solar irradiation. (4) Decrease of the blood coagulation time.

A reduction of blood-pressure has also been reported after radiation from carbon arc sources. In all probability this is not a specific effect, but due to luminous and infrared components in these rays.

6. **Effects on Metabolism.**—In rickets, both experimental and infantile, it has been shown that the beneficial action of radiant energy is not limited to the rachitic process. It supplies something which makes metabolism more efficient, causing the organism to operate with increased economy (Laurens[13]).

Blood sugar of the normal person is not influenced by ultraviolet irradiation, but that of some persons with diabetes may be temporarily diminished. Irradiation of moderate intensity increases endogenous nitrogen metabolism. Irradiation may double the fat content of the blood, cholesterol increasing by 30 per cent. It makes respiration easier, deeper and less frequent, although total ventilation per minute remains constant. Basal metabolism is not influenced. Ultraviolet rays exert a glycogen-storing effect, prevent lowering of the respiratory quotient after muscular exercise. The rays have no influence on thyroid activity.

Although light is one of the most striking attributes of the environment of living organisms, the results of practically all of the experiments go to show that its effects on the normal growth processes of animals have been negative (Laurens).

CLINICAL USES OF ULTRAVIOLET RADIATION

In extolling the curative effects of ultraviolet therapy from non-specified sources on a large number of pathological conditions early enthusiasts failed to take cognizance of two facts; one is that while speaking of ultraviolet in treatment, an admixture of infrared, visible and ultraviolet radiation is employed; the second is that in many of these conditions similar or perhaps even better results may have been achieved by visible and thermal radiation alone. In employing heliotherapy along with ultraviolet there is not only the large amount of visible and infrared to consider, but also climatic conditions and other factors.

The ideal situation, according to some authors would be to discontinue the use of the term ultraviolet and substitute either a more exact designation which would associate the range of radiation employed with some definite physiological action such as erythema producing rays or, instead, prescribe a certain wave length of effective intensity.

The following summary of the established clinical uses of radiation from ultraviolet sources is therefore presented with due qualification by the preceding statements. Further details will be found in the special chapters in Part V.

Metabolic Disorders.—In rickets experimental work of Hess[10] and Huldschinsky[11] has definitely established the specificity of ultraviolet radiation, and this disease has become the criterion of appraising the biological action of the ultraviolet rays in the region of 3000 Angstroms. It is emphasized by all clinicians that this radiation not only cures rickets but also materially benefits the child's general health. Prenatal irradiation of the mother and also irradiation of the nursing mother has a definite preventative influence on rickets. Infantile tetany or spasmophilia, the minor degrees of calcium and phosphorus deficiency, marasmus in children and osteomalacia in pregnant or nursing women also respond favorably.

Tuberculosis.—Both sunlight and artificial radiation are of definite value in many forms of tuberculosis. Sunlight (especially in the highlands) is the treatment of choice for the treatment of tuberculosis of bones and joints, lymph nodes and the genito-urinary tract without active pulmonary tuberculosis. Results are excellent if sunlight is employed over prolonged periods. Artificial radiation should be used, in addition, on cloudy days, especially in cutaneous tuberculosis or discharging sinuses. Artificial radiation may be preferable to sunlight for such complications as superficial, peritoneal and intestinal tuberculosis. General exposures are always made with additional local exposures over the disease area.

In extrapulmonary tuberculosis with active pulmonary tuberculosis accompanied by fever, sunlight of low intensity is the treatment of choice for the bones and joints and genito-urinary tract. The mercury quartz light often is preferred when pulmonary disease is exudative and febrile, because of the relative absence of heat rays. It is advisable to alternate mercury quartz irradiation with exposure to outside air and diffuse daylight. In acute progressive tuberculous laryngitis, local ultraviolet irradiation is inadvisable until the acuteness has subsided; it may be tried as final treatment if other measures have failed.

Ocular tuberculosis and aural tuberculosis respond infrequently to light. Oral tuberculosis is most resistant. Fistulas are often resistant, but postoperative sinuses are most responsive. Intestinal, peritoneal and lymph node tuberculosis often are rapidly responsive to ultraviolet therapy.

In pulmonary tuberculosis there is some division of opinion among clinicians regarding the desirability of light therapy, with the majority favoring it in all except active and feverish cases. For further details see Chapter on respiratory condition.

Skin Conditions.—In lupus vulgaris, carbon arc therapy applied in the Finsen method is of specific value. In erysipelas ultraviolet is safe and successful especially in the very young and the old, but since this disease responds so well in all ages to sulfonamides, ultraviolet therapy is being used less frequently. According to the Council on Physical Therapy it is reasonably well established that ultraviolet is at times useful either alone or as an adjuvant in acne vulgaris, adenoma sebaceum, pityriasis rosea, parapsoriasis, psoriasis, telangiectasia, indolent ulcers and wounds. In the last two groups the admixture of infrared and visible radiation is undoubtedly helpful and may often alone accomplish similar results. Ulcers occurring in Raynaud's disease or thrombo-angiitis obliterans and also old chronic varicose ulcers respond poorly to ultraviolet.

Miscellaneous Conditions.—In selected forms of general debility and secondary anemia, in convalescence after operations and infectious diseases, in chronic bronchitis and sensitiveness to acute respiratory disorders, in bronchial asthma, light therapy has proved a valuable adjunct to general medical treatment. There is fairly uniform agreement as to the frequent benefits of general irradiation in improving appetite and sleep. Marked mental stimulation and analgesic effect on painful areas may be explained by reflex action.

Counterirritation of a definite area of the skin by a measured erythema reaction from sunburn to blistering, has been recommended by Eidinow[7] for selected cases of acute pain in brachial and sciatic neuritis, lumbago, fibrositis, etc.; in swelling of joints due to effusion of fluid, in long-standing asthma with signs of bronchitis and emphysema. The rationale of this treatment may be partly explained by an absorption of the destroyed albumin in the irradiated area, amounting to a non-specific protein "shock" and partly by reflex stimulation from the irradiated "zone."

Selected cases of inflammatory and ulcerative conditions of the mucous membranes in eye, nose and throat as well as in genito-urinary and gynecological diseases, may respond favorably to ultraviolet irradiations; for details see respective chapters.

Ultraviolet irradiation of the blood has been reported as effective in acute pyogenic infections and acute thrombophlebitis. For details see Chapter XIX.

CONTRAINDICATIONS TO ULTRAVIOLET RADIATION

In active and progressive forms of pulmonary tuberculosis irradiation may be followed by an increase of fever, loss of weight and a fall in blood-pressure. The same reaction has been reported in cases of children with tracheo-bronchial adenitis. In tuberculous patients the rapid appearance of intense pigmentation accompanied by a decline in the blood-pressure suggests the likelihood of involvement of the suprarenal glands and should cause suspension of the irradiation.

Advanced cachexia or inanition from any cause, advanced heart disease with failure of compensation, advanced arteriosclerosis, gross renal or hepatic insufficiency are all absolute contraindications to actinic radiation. In aged people, milder forms of acute or chronic nephritis or myocarditis also contraindicate irradiation.

In hyperthyroid subjects and patients with diabetes, severe itching and annoying general symptoms may occur after irradiation; highly nervous people are often made worse and at times show marked pruritis. Menstruation is not necessarily a contraindication to irradiation, although it may be more convenient to omit irradiation during the menstrual period.

All forms of generalized dermatitis as a rule serve as a contraindication to ultraviolet irradiation. In eczema, psoriasis, lupus erythematosus, herpes simplex, erythema solare perstans, xeroderma pigmentosum, freckles, atrophy, keratoses, prematurely senile skin, irradiation may cause an exacerbation, provoke an attack or cause other injurious effects.

The possibility of producing cancer in the skin by ultraviolet has been receiving some study in recent years. According to the Council of Physical Therapy,[5] if the cells of the basal layer of the skin receive an excessive quantity of radiant energy, the two protective processes of cornification and pigmentation become abnormally great (hyperkeratosis and hyperpigmentation) and a third degenerative process starts. Persons lacking in pigment or much exposed to ultraviolet rays show the highest percentage of skin cancer. The developing neoplasm occurs in the place of greatest proliferation, beginning in a wartlike hyperkeratosis, a precancerous change. A cancer develops from a precancerous lesion not only as a result of continuation of the initial insult but from any continued trauma. Thus ultraviolet rays do not cause cancer in themselves but produce characteristic cell changes leading to precancerous lesions in the skin. Any irritation, including continuously and excessively applied ultraviolet rays, can cause the precancerous change to become malignant.

The eyes may be harmfully affected by ultraviolet as is commonly known. Sunlight is ordinarily harmless but when the ultraviolet component is increased by reflection it produces "snow blindness." Glowing arcs and metals which emit energy shorter than 2950 Angstroms are injurious, and special ultraviolet-absorbing glasses should be worn. The damage usually is limited to conjunctivitis and blepharitis with pricking pain and uncomfortable foreign body sensation. Edema, contraction of lids and corneal erosion may occur. Long exposure to intense ultraviolet rays may produce functional disturbances, such as color scotomas and constriction of the peripheral field. It is still a question whether intense ultraviolet rays produce lenticular cataract.

Further aspects of the dangers of light therapy will be presented at the end of the Chapter on artificial light treatment.

Photosensitization.—Photosensitization is a condition in which certain drugs or substances when present in the system during ultraviolet irradiation cause an increased (photocatalytic) reaction consisting of severe dermatitis. Some of these substances are: (1) Drugs: quinine, trypaflavin, eosin, methylene blue and other fluorescent dyes; (2) endocrines: insulin, adrenalin, pituitrin, thyroid; (3) heavy metals: such as mercury, iron, bismuth, gold, silver and calcium and their salts. When circulating in the blood, these metals not only increase the effect of radiation, but their own action is also markedly increased by radiation.

Photosensitization can serve to increase the effectivess of radiation; this has been done by the indirect administration of fluorescent substances, notably eosin and by external use of certain substances, notably coal tar (see psoriasis).

The sulfonamides have been described as photosensitizers by some and declared innocuous by others. Lately it has been even claimed that sulfonamides placed on the skin protect it against light erythema.[23]

There are a few individuals who seem to have an inborn sensitivity to both sunlight and artificial radiation. They may react with severe itching or with rapidly developing dermatitis.

The only way to detect and ward off the dangers of abnormal sensitivity is to administer ultraviolet radiation in all doubtful cases in carefully measured, subminimal doses.

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CHAPTER XVIII

HELIOTHERAPY

Historical. Physics of Solar Radiation. Clinical Considerations. Technique of Heliotherapy. Sun Bathing in Well People and Children. Ultraviolet Transmitting Window Glass.

Historical.—The great health temple erected to Æsculapius, God of the Sun, Medicine and Music, built at the time of Hippocrates, some four hundred years before Christ, served for the administration of light and water to cure disease and for the pursuit of physical and mental culture. Hippocrates prescribed sun baths for wasted muscles and employed a protective head covering for patients exposed to the sun's rays. Another Greek surgeon, Antylleus, recommended sun baths for the reduction of obesity and for the treatment of slow healing ulcers. Both Greeks and Romans were in the habit of taking daily sun baths. A solarium was part of every Roman dwelling house.

During the early days of the Christian era and all through the Middle Ages no progress was made in the curative uses of sunlight. The cause was a revolt against Paganism associated with sun worship. As the darkness of the Middle Ages began to lift, medical men in England, France and Germany started to advocate the treatment of wounds, rheumatism and nervous conditions by sunlight. It remained, however, for a non-medical man, Arnold Ricli, a Swiss, to popularize sun baths. Many of the patients were cured, but Ricli's lack of medical knowledge prevented him from advancing the scientific use of sunlight.

Two Swiss physicians, Bernhard and Rollier, are responsible for the present-day world-wide recognition and extensive use of the "sun cure." Both practiced in the high Alps where sunlight was abundant and powerful. Bernhard was the first one to publish, in 1902, the remarkable results following the local sun treatment of sluggish wounds and cases of external tuberculosis. Rollier began his work, in 1903, at Leysin by systematic general sun treatment of all forms of surgical tuberculosis. In addition, he developed a method for the prevention of tuberculosis in delicate children with predisposition to tuberculosis. Rollier's work has served as a model for similar work throughout the civilized world.

Physics of Solar Radiation.—The term heliotherapy signifies the systemic exposure of the nude body to the rays of the sun for treatment purposes. In evaluating the therapeutic factors in heliotherapy one must take into consideration: (1) the sun's energy; (2) climatic factors, such as open air, altitude, rest or exercise. No form of artificial light treatment can fully replace all these factors.

The *sun's* radiation represents a blending of infrared, luminous and ultraviolet radiation.

As shown in this table, about 60 per cent of the energy in the sun's radiation is in the infrared region and 40 per cent is visible and ultraviolet. There exists great variation in the percentile relationship between the ultraviolet, visible and infrared. There are six principal causes of variation in solar radiation intensities at the surface of the earth: (1) variations in the amount of energy radiated from the sun, (2) variations in the earth's solar distance (seasons), (3) amount of water vapor in the atmosphere, (4) dustiness or haziness in the atmosphere, (5) zenith distance of the sun (time of day), (6) altitude above sea level.

Table 41.—Distribution of Solar Energy (After C. E. Greider and A. C. Downes)

Watts × 10^{-7} per Square Millimeter

	Antirachitic ultraviolet, 2900 to 3100 A°		Non-penetrating ultraviolet and visible, 3100 to 6500 A°		Penetrating red and infrared, 6500 to 14,000 A°		Non-penetrating infrared, 14,000 to 120,000 A°		Total
	Amt.	Per cent	Amt.	Per cent	Amt.	Per cent	Amt.	Per cent	
Springfield Lake, Ohio	1.2	0.014	2894	35.0	3660	44.1	1760	20.9	8,290
Cragmore, Colo.	1.6	0.016	3534	36.0	4432	45.1	1860	18.9	9,828
Mt. Wilson, Zenith, calculated	14.0	0.12	4630	39.6	4410	37.7	2646	22.6	11,700

Daylight consists of direct solar radiation, diffuse radiation from the sky (skyshine) and radiation reflected from surroundings, such as buildings. There is a relatively higher amount of ultraviolet in the skyshine than in direct sunshine. The ocean, the sandy beach, the snow furnish a diffuse and at times a very powerful form of sunlight which is therapeutically valuable. The large amount of ultraviolet in skyshine accounts for the fact that it is possible to get sunburned on a beach on a cloudy day when there is no direct radiation from the sun. The reflection of ultraviolet from the surface of water is twice as great as from a field of grass, but only one-fourth as much as from freshly fallen snow.

The ultraviolet in the sunlight increases at high altitudes in percentage at the expense of the infrared. At lower altitudes a great deal of ultraviolet is absorbed by the water vapor of the atmosphere and even more by the smoke and dust over cities. At no time can one obtain from sunlight wave lengths shorter than 2900 Angstroms and in the winter season, when the sun's position is low on the horizon, not even the wave lengths of 3000 Angstroms are available. In a series of experiments Tisdall and Brown[11] of Toronto exposed rats in different cages for two-hour periods at different hours of the day and noted the maximum altitude of the sun. Only when the sun's altitude was 35 degrees or more did the light have much antirachitic effect. This altitude is not attained at all in Toronto during the winter months. Tonney, Hoeft and Somers[12] have shown that in the downtown loop district of Chicago during the months of October to February the ultraviolet content of sunshine is seldom strong enough to provide a minimum erythema dosage. The noon June sunlight has six times the amount of ultraviolet of the noon December sunlight. Mayerson, Graham and Laurens[8] at New Orleans in a ten-year study of monthly averages of the total antirachitic energy (sun and sky) found high values both in sun and sky during the late spring and summer; at the same time at low solar altitudes, during fall and winter, the antirachitic radiation in the sky may equal or exceed that of direct sunshine.

The large variations in the amount of ultraviolet make a generally applicable accurate dosing of the sun's radiation quite impossible; on the other hand heliotherapy is being successfully administered at high as well as low levels and at the seashore. In or near large cities the necessity of exposing the unclothed body is an additional problem.

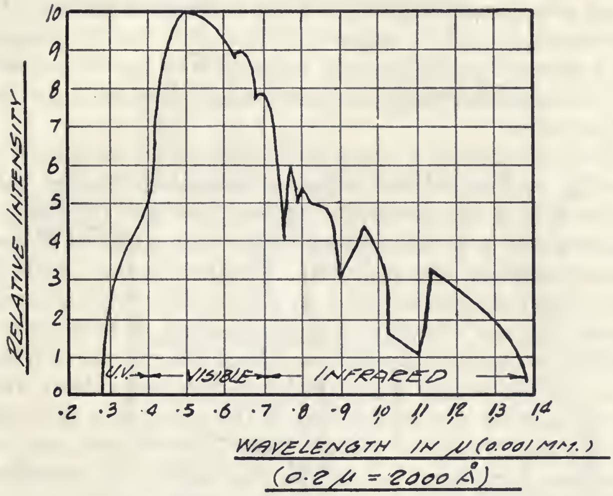

FIG. 226.—Sunlight spectral energy distribution.

CLINICAL CONSIDERATIONS OF HELIOTHERAPY

The two large groups of disease conditions specially amenable to heliotherapy are non-pulmonary or surgical tuberculosis: tuberculosis of the skin, bones, joints, of the genito-urinary tract, the intestines and larynx; the other group is that of pulmonary tuberculosis. It is generally recognized that in both of these conditions heliotherapy is at best only a valuable accessory to general treatment. Among the most evident clinical effects of heliotherapy are a better appetite and sleep and a replacement of fatigue and pain by greater liveliness and euphoria. Definite improvement occurs in the skin which from a flabby, thin consistence rapidly changes to a firm, tanned appearance; the subcutaneous tissue also fills out so the skin cannot longer be grasped in loose thin folds; finally, the muscles regain tone and firmness, even despite prolonged bed rest for joint immobilization. As an indication of the clinical progress of the patient, the sedimentation rate also improves. All these changes occur especially rapidly in cases of surgical tuberculosis but can also be looked for in pulmonary cases after a sufficiently long period of well controlled sun baths.

In conjunction with the general improvement there is a gradual or rapid amelioration of some of the local symptoms. Rollier[10] emphasizes the remarkable analgesic action of heliotherapy in surgical tuberculosis. In cases of arthritis and coxalgia, after a few treatments all pain may disappear. Tuberculous lesions of bones and joints undergo progressive favorable changes, especially if the treatment is combined with suitable immobilization and is continued for a sufficiently long period. Patients with tuberculous peritonitis, or intestinal tuberculosis show gradual improvement. There is a marked resolving action on infiltrations and edema; as also the gradual return of function in many joints with old-standing ankylosis. Open tuberculosis, on account of the prevailing mixed infection, responds much less readily to insolation.

In pulmonary tuberculosis, the main object of heliotherapy is to increase the patient's general health and resistance without interfering with the degree of rest considered necessary for the individual patient. No miraculous improvement should be expected but a slow steady improvement in the patient's general condition and, indirectly, of his tuberculous lesions, as shown by a diminished cough and sputum and diminishing of the physical signs over the lungs.

Treatment by sunlight as a whole is desirable in the treatment of tuberculosis, according to Phelps[9] and other investigators, rather than by any one particular part of the spectrum. Others conclude that since the treatment of tuberculosis is as satisfactory in the mountains as at the seashore, it is not alone the short ultraviolet rays, obtainable only in the mountains, but also the longer ultraviolet rays, in conjunction with the visible violet and blue rays, that are effective; a great quantity of these rays is present in the sunshine in mountains and near the seashore, where refraction and reflection by the water and the white sand augments them; furthermore, result of treatment by the winter sun in the mountains is excellent when admittedly no wave lengths shorter than 3130 Angstroms are present. There is general agreement as to the desirability of heliotherapy over artificial light treatment in suitable locations because of its inexpensiveness and because of the additional advantages of climatotherapy.

Contraindications to heliotherapy in high altitudes are nephritis, ulcerous enteritis with diarrhea, decompensated cardiac lesions, amyloid degeneration. Further clinical aspects of pulmonary tuberculosis will be discussed in the Chapter on respiratory conditions.

A survey[4] on heliotherapy in connection with tuberculosis sanatoria in the United States showed that facilities for it are quite uniformly present. Most of the institutions have convenient arrangements on porches, on roof solariums or in sun pens. As regards artificial heliotherapy, there is a considerable variation in equipment. Many of the larger sanatoriums, especially those which also conduct a preventorium service, have large and well equipped heliotherapy departments for treatment *en masse.* In others portable lamps are used.

It appears that in the use of heliotherapy the tuberculosis institutions adhere fairly closely to the methods and indications now generally accepted. A few, however, employ heliotherapy as a routine procedure for practically all patients regardless of the type, stage or activity of the disease. Of the 602 institutions that replied to the questionnaire, 440 reported facilities for artificial heliotherapy and a total of 1,589,720 treatments: 1,114,709 for adults, 320,704 for children and 154,307 not classified.

TECHNIQUE OF HELIOTHERAPY

Heliotherapy can be practiced equally well at high and low altitudes. A sufficient amount of sunshine and clearness of the atmosphere are, however, prerequisites.

The generally accepted scheme of procedure—especially in mountain resorts—is to begin by training the patient to grow accustomed to exposure to the air without sunshine. The patient is supplied with a hat, with protecting eye glasses and bathing slips and lies on his bed first in the shade for a few days. This aërotherapy plays an important part in the early part of the treatment because it accustoms the patient to expose his skin which has usually a flabby, unhealthy appearance and has been heretofore covered with too many garments. There is a powerful tonic reaction from the cool air in motion, especially in the mountains.

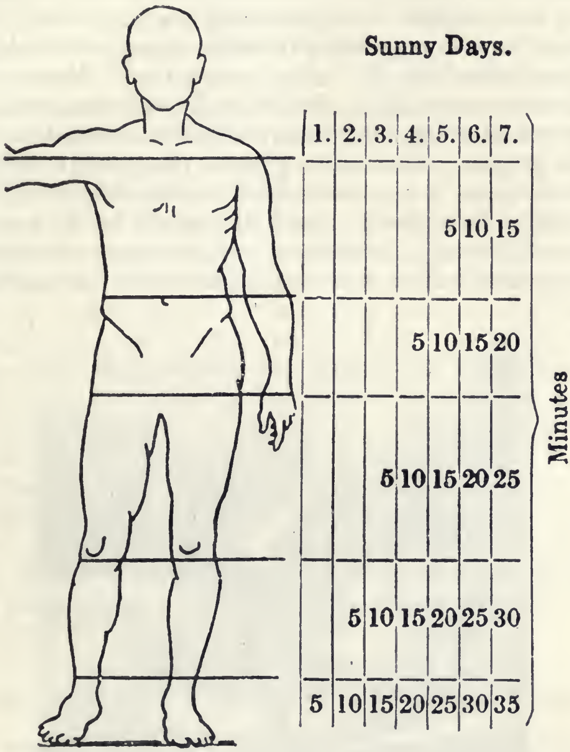

Fig. 227.—Diagrammatic chart of exposure to heliotherapy. (After Rollier.)

After a few days, gradual exposure of the body to the sun begins. The aim is to employ rather suberythemal doses, first to a small portion of the body and gradually to increase both the length and the area of exposure. The scheme of "progressive insolation" developed by Rollier and shown in Figure 227 may serve as a model; it calls on the first day for baring of the feet for five minutes only; next day the legs are exposed for five minutes, and a total of ten minutes is given to the feet. Within five days, exposure of the entire front of the body is reached and on the sixth day exposure of the entire back is begun for five minutes. The head is never exposed and the eyes are always protected against the glare by suitable glasses.

The purpose of gradual exposure is to determine the patient's individual sensitivity and to stay always within less than sun-burn doses. Various parts of the body differ in sensitivity according to the thickness of the protective horny layer. The subjective and objective reactions (rise in temperature and pulse, erythema) must be carefully watched. Patients are best treated in the recumbent dorsal or ventral positions and may alternate between these if the condition permits. Following this systematic exposure the body gradually becomes tanned and finally it becomes possible to reach an average of three to four hours' total exposure time in winter and of two to three hours in summer.

The best hours for exposure are those when the air is clear and the heat is moderate. In the mountains in summer these are the early morning hours between 7 and 11 A.M., and in winter from 10 A.M. to 3 P.M.

In carrying on a regime of heliotherapy it is important, according to Mayer[7] that patients during and after solar exposures should feel as well as or even better than they did before taking them. Headaches, restlessness, nervousness or irritability, elevation of body temperature over 98.6 or pulse-rate over 90 are all indications of undue reactions that call for some change in the program. Overheating is the chief danger of general light treatment. One must be especially careful when the sun is very hot and there is no wind. In patients lying fully clothed in the sun overheating much more readily occurs. In patients with a stronger constitution a short cold spray or shower after sun baths often exerts an additional tonic effect.

FIG. 228.—Patient treated at Rollier's. This is a case of spinal tuberculosis immobilized in ventral position; the patient rests on elbows and has hands free for work. The head is protected against the sun.

Sun Bathing in Well People and Children.—Sun bathing is deservedly popular and the caged-in office dwellers of big cities can get definite benefits from careful exposures to the summer sun after having missed its stimulating rays during the dreary winter months. However, adult individuals react in different ways and so do children, adults and the aged. The differences in the reactions of blondes and brunettes are generally known and there may occur severe reactions due to abnormal sensitivity or in the presence of light sensitizing substances.

Overexposure to sunlight may cause varying degrees of sunstroke, heat stroke or sun burns and such symptoms as headache, lassitude, undue fatigue, irritability or gastro-intestinal upset. Properly applied on the other hand, sunshine and open air will act as a powerful tonic, increasing general powers of resistance and promoting mental and physical development. For this reason the duration and extent of exposure to sunshine should be carefully graduated and those who do not pigment efficiently or easily should be warned to be especially careful.

In robust *young adults* or in fairly well persons who take sun-baths for tonic purposes only, exposure of the entire body can be carried out, beginning with a total of eight minutes' exposure to four surfaces (including the two sides) of the body. Healthy persons not accustomed to the sun should never expose themselves for more than fifteen minutes at first and increase this exposure five minutes daily during two weeks.

Exposure of *babies and children* must take place under an even more careful control of dosage on account of the more sensitive skin. A child, aged from six to eight months, may be started at one-half minute on the back and one-half minute on the front, once a day, for two weeks; this dosage may be increased with one minute each day for two weeks until a total exposure period of six minutes per day and no more is reached. The head and eyes should always be protected and on very warm days no exposure be given during the noon hours. Children aged from eight months to two years—who are especially benefited by the preventive applications of sun-baths—may be started on fractional body exposure, using a scheme as follows: first four days: expose the chest, arms and small part of the back for three minutes; next four days: increase exposure to five minutes; next week increase exposure of arms up to fifteen minutes; third week: expose in addition abdomen for three to five minutes and beginning the fourth week, the entire body for three minutes at first, increasing it to ten minutes within twelve days, continuing treatment of the arms and chest for a total of thirty minutes. After the second year children may be exposed similarly to the schedule for adults.

ULTRAVIOLET TRANSMITTING WINDOW GLASS

Ordinary window glass does not permit the passage of ultraviolet rays, chiefly on account of its content of iron oxide. Glass made of clear silica (quartz) transmits practically all of the ultraviolet rays of sunlight. Such window glass can be employed as an auxiliary in heliotherapy. It has been much advertised not only for use in hospitals and nurseries, but also for schools, office buildings and homes, on the ground that it permits the exposure to sunlight, especially in winter in situations where it would be impractical or uncomfortable to expose the nude or partly or even fully clothed body to the sunshine of the open air. As a result of this propaganda, expensive instalments have been made in many places with these glasses.

The National Bureau of Standards reports on some of these window glass substitutes as shown in Table 42.

Tests reported on by the Council of Physical Therapy[3] showed that only those glasses which have a transmission of 30 per cent or higher, at 3020 Angstroms, gave an appreciable protection against rickets, but this protection was not 100 per cent. The ultraviolet-lamp radiation gave

100 per cent protection. It was also shown that subsequent to a period of exposure to the sunlight a physical and chemical change known as *solarization* takes place in these glasses, which decreases the amount of ultraviolet transmission. Coblentz[2] reports that the newer types of glasses made especially for transmitting short-wave ultraviolet solar radiation, after complete solarization have a transmission of 40 per cent or higher of the incident radiation at wave lengths of 3020 Angstroms; this renders these glasses efficient as being within the limitations of the ultraviolet by other factors. Moisture proof cellophane may be used as an efficient ultraviolet transmitting window pane, according to Krusen,[5] transmits about 60 to 70 per cent of the available radiation at 3000 Angstroms, develops a yellow discoloration slowly and can be replaced easily and cheaply.

Table 42.—Total Transmission, When New, of Solar Ultraviolet Rays to Which Common Glass is Opaque

	Per cent
Fused quartz	92
Corex D	92
Helioglass	50
Vitaglass	50
Cel-o-glass	20
Quartz-lite	5
Flexoglass	1
Common window glass	0 to 5

It is evident that when there is no applicable ultraviolet present in the sunlight, such as in the winter months, these windows cannot transmit any. Clark[1] states that in March in a north room equipped with ultraviolet transmitting windows, a child would have to sit in a place where the illumination is 10-foot candles for at least twenty hours to get as much ultraviolet radiation as he would get in two minutes outdoors in sunlight at noon. It is therefore a sheer waste of money to equip business offices and school rooms with these glasses.

Solaria of special glass are useful in hospitals and sanatoria where patients can be exposed just as for outdoor sun treatment, but with protection against drafts and chilly atmosphere. These windows must be carefully cleansed from accumulation of dust and dirt which cuts down their ultraviolet transparency considerably; the increased transparency for heat and light rays and lack of sufficient ventilation often make the atmosphere as oppressive as that of a hothouse.

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CHAPTER XIX

ARTIFICIAL ULTRAVIOLET THERAPY

General Considerations. Historical. Carbon Arcs: Radiation Characteristics, Relative Advantages and Disadvantages. Quartz Mercury Vapor Arcs. Hot Quartz Lamps, Cold Quartz Lamps. Low Pressure Mercury Arcs. Electrodeless High-frequency Induction Lamps. Choice of Ultraviolet Generators and Standards of Ultraviolet Emission. Technique of Artificial Ultraviolet Irradiation. Special Techniques of Ultraviolet Irradiation. Local Irradiation. The Finsen Treatment. Ultraviolet Blood Irradiation. Air Sterilization. Dangers of Light Therapy.

General Considerations.—The sun has been described as the greatest physician of all, the only trouble being to get an appointment with him. The difficulty of applying heliotherapy with regularity and under constant conditions, especially in lowlands and cities on one hand and the easy availability of a great variety of dependable sources of artificial radiation on the other, has made recourse to artificial sources of radiation an established necessity.

However, even in artificial sources of radiation there may be considerable difference in the proportion and intensity of the various wave lengths, as indicated in Table 43. Furthermore, while we speak of ultraviolet rays, the fact holds that in most instances we are using infrared and visible radiation together with the ultraviolet.

TABLE 43.—PRINCIPAL FORMS OF PHOTOTHERAPEUTIC RADIATION

Source	Predominant rays	Approximate wave lengths
Heating elements	Infrared	120,000 to 6000 A°
Incandescent lamps	Infrared and visible	50,000 to 4000 A°
Carbon arcs	Infrared Visible Long ultraviolet	120,000 to 2400 A°
Low voltage mercury arc (hot quartz)	Visible Long and short ultraviolet	30,000 to 2000 A°
High-frequency induction lamp	Long and short ultraviolet	10,000 to 2000 A°
High voltage mercury arc (cold quartz)	Short ultraviolet	Almost all at 2540 A°

Historical.—Artificial light therapy had its inception in Niels Finsen's classical experiments, done in 1893, at Copenhagen, showing that the ultraviolet or chemical rays of sunlight have stimulating and bactericidal effects on lower organisms. Employing carbon arc light which just then came into use for lighting, he filtered out the heat rays through water and achieved excellent results in the treatment of tuberculosis of the skin (lupus) by concentrated carbon light. The mercury vapor or quartz lamp was developed from the Cooper-Hewitt lamp of 1891, in which mercury vapor was excited by an electrical current for lighting purposes. In 1903, Heræus devised tubes from fused quartz transparent to ultraviolet rays and allowing intensive radiation without the danger of exploding the tube. Bach and Nagelschmidt developed the quartz mercury vapor lamp for general radiation and Kromayer the "water-cooled" mercury vapor lamp for contact treatments. In recent years many newer, efficient forms of ultraviolet generators have been developed.

CARBON ARC LAMPS

Construction.—The principle of construction of carbon arc lamps is as follows: Two carbon rods or electrodes are held in the lamp so that their

FIG. 229.—Arc stream in carbon arc radiation.

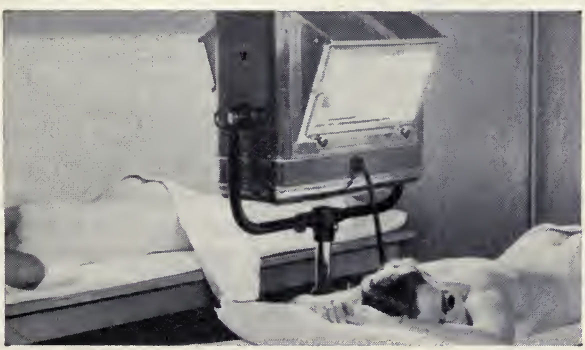

FIG. 230.—Two bed carbon arc lamp. (Courtesy of National Carbon Company.)

free ends are opposite each other. They may be vertically, horizontally, or otherwise arranged, and may be of several different sizes. The far ends of these electrodes are connected through suitable resistances or reactances with a source of direct or alternating current. As the current is turned on and the two free ends of the carbons are brought into contact, an electric circuit is established. The points in contact with each other become very hot as the electric current passes through them. The carbons are then separated by a suitable arrangement, which may be a spring or motor mechanism and the current continues to flow through the circuit even though the electrodes have become separated. The electric current flowing across the gap is called an arc.

Modern arc lamps are entirely automatic in operation and are started or stopped by the throw of a switch. They vary according to the amount of power they consume, the amount of radiation they emit and the kind of electrode employed, which determines the kind of radiation emitted.

Carbon arc lamps large enough to be useful for general body treatment in a physician's office where individual patients are treated may use as much as 40 amperes at the arc but draw only 15 amperes or less from the electric mains and can, therefore, be used on any convenient outlet. Hospital type arcs applicable to institutional treatments are large enough to give therapeutic quantities of radiation over entire hospital wards so that large groups can be treated at once from one lamp, but they require special wiring.

The electrodes in carbon arc lamps may be solid carbons or may be carbon tubes impregnated with various metals. In Europe pure metal electrodes, like tungsten or iron, are also employed. The lamps may be equipped with single, double or four pairs of electrodes. The multiple electrode type prevents waste of current and, when suitably arranged, permits the treatment of several people placed in a circle around or underneath the lamp. Solarium types of both mercury vapor and carbon arc lamps have been found useful in large institutions for group irradiation.

A proper balance between the strength of the current and the size of the carbons is essential for efficient radiation.

In using carbon arc lamps on direct current the temperature of the electrode at lower potential (called the positive electrode) is raised considerably higher than in the negative electrode. The crater forms at the end of the positive electrode, and thus it burns up quickly. With the alternating current the consumption of carbons is equal on both ends.

Radiation Characteristics.—The radiation of arc lamps is emitted from two sources. (1) The glowing ends of the electrodes are very hot. These tips emit radiation the same as any other incandescent body. Spectral analysis shows that this radiation has a continuous spectrum with all wave lengths present. (2) The arc stream itself or the path of the current through the gap between the ends of the electrodes is much more important. It is the source of most of the radiation from the carbon arc. Its spectral analysis shows a line or band spectrum consisting of lines or bands of definite wave lengths. This radiation comes from the vapors of the metals being melted and volatilized at the ends of the electrodes. In the case of iron and other heavy metals, this radiation from the arc stream consists of a multitude of lines so closely spaced that unless a powerful spectroscope is used the radiation appears to be continuous. Different metals give different kinds of radiation and the kind desired can be obtained by selecting the proper type of electrode.

The carbon arc furnishes a radiation more nearly like sunlight, with the following differences: there are more shorter rays present in the ultraviolet zone than in the sun, there is less luminous radiation and a more intense infrared emission present. (See Frontispiece.)

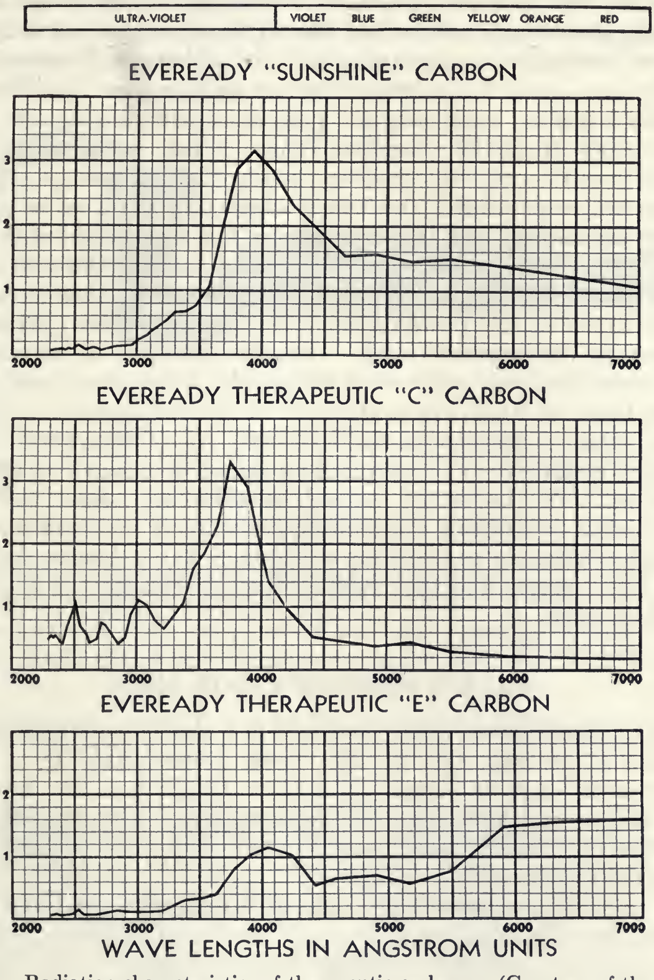

FIG. 231.—Radiation characteristics of therapeutic carbons. (Courtesy of the National Carbon Company.)

The intensity and quality of radiation from carbon arcs depends on (1) the kind of carbons and their size, (2) the direction of current when direct current is employed, and (3) the amount of current employed. It is important that the various kinds of carbons be employed in suitable lamps because the efficiency of output depends on the correct proportion between voltage, amperage and the diameter of the carbons.

There are three types of carbons available at present: (1) the *sunshine* type of carbon furnishes an artificial source of radiation more nearly like sunlight than any other artificial source. It contains cerium and other rare earth type elements in addition to carbon. Radiation from this arc when applied through a Corex D glass screen furnishes a spectrum ranging from 2900 to 40,000 Angstrom units, which is very similar to outdoor sunlight. (2) Therapeutic "C" carbons. "*C*" type carbons contain iron, aluminum and nickel, in addition to carbon. Arcs with this type are designed to produce a maximum amount of ultraviolet of the short-wave region from 2000 A. U. to 3100 A.U. These regions chiefly produce erythema and antirachitic effects. In the untanned skin of an individual of average susceptibility to sunburn the "C" carbons will produce a first degree erythema with one minute exposure at 36 inches. (3) Therapeutic "E" carbons contain strontium and produce maximum amounts of radiation from 7000 to 10,000 Angstrom units, which is the radiation that penetrates deeply into subcutaneous tissue, thereby assisting in raising subcutaneous temperatures, and useful where infrared is to be applied.

Relative Advantages and Disadvantages.—The carbon arc is the hottest artificial source of radiation readily obtainable and in this respect is the closest approach to sunlight. (Coblentz.[6]) The early makes of carbon arc lamps employed in the United States were unsatisfactory, because their radiant energy emission was weak. The arcs sputtered on account of the current fluctuation and unpleasant fumes and ashes were produced. In the newer types of lamps the problem of fumes and sparks is solved by a perfected system of ventilation and screening. The full power of the lamp is developed instantly, so no warming-up period is required as in mercury vapor lamps. The lamps are rugged, portable and, since they consist chiefly of metal, reasonable mechanical shocks have no effect upon them. On the other hand, in comparison to mercury vapor lamps, carbon arcs consume more current and their carbons have to be adjusted and replaced from time to time.

QUARTZ MERCURY VAPOR ARCS

Mercury, a fluid metal, when vaporized in a quartz container by intense heat, emits a spectrum rich in ultraviolet, characterized by a series of intense spectral lines or bands. The wave length and flux intensity of these bands vary according to the construction of the generator. (See comparative spectra of quartz mercury arc and high voltage mercury discharge on frontispiece.)

In the original quartz mercury lamp an electric arc produced between two electrodes vaporizes the mercury in the quartz burner. These arcs operate at a high vapor pressure, large current consumption and relatively high temperature and are known as *hot quartz lamps*. Newer mercury vapor lamps come in three principal types: (1) *Low-pressure mercury arcs* in which mercury becomes vaporized through a tungsten filament heated at low voltage in a quartz container, (2) *cold quartz lamps* in which a high voltage current illuminates a mixture of neon gas and mercury vapor contained in a quartz tube or other special container, (3) *electrodeless induction lamps* in which a high-frequency coil encircling a quartz bulb containing a trace of mercury induces a mercury vapor glow.

Hot Quartz Lamps.—In all quartz vapor lamps the principal part is the "burner," a fused quartz tube, air exhausted and containing mercury, with suitable attachments to conduct an electric current to it.

The older type burners contain a large amount of mercury. After turning on the current the burner has to be slightly tilted: this makes the mercury run across the vacuum and for a moment complete the circuit.

The heat generated immediately vaporizes enough of the mercury to fill the tube; this vapor continues to conduct the current and thus more and more of the mercury is vaporized, resulting in gradually more intense radiation. In contrast to the carbon arc lamps, the arc of which is struck at nearly full intensity as soon as the lamp begins to function the older mercury vapor arc lamps require from five to ten minutes to "build up" so that treatment must not be started earlier.

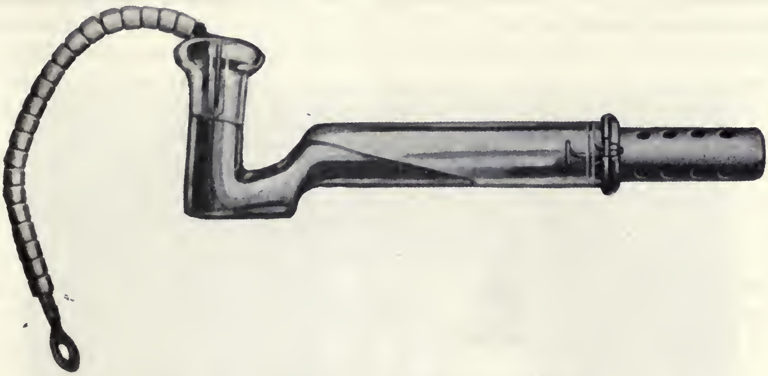

FIG. 232.—Older type tungsten-mercury burner.

The newer type of hot quartz mercury arcs consist of a straight length of fused-quartz tubing, containing a small, measured quantity of mercury and a small amount of rare gases to provide a quickly available vapor to start the discharge. These burners operate on 220 volts alternating current which is provided by a suitable transformer. As soon as the current is turned on the tube lights up due to the arc passing through the inert gas atmosphere. The mercury is at once vaporized and a very brilliant mercury

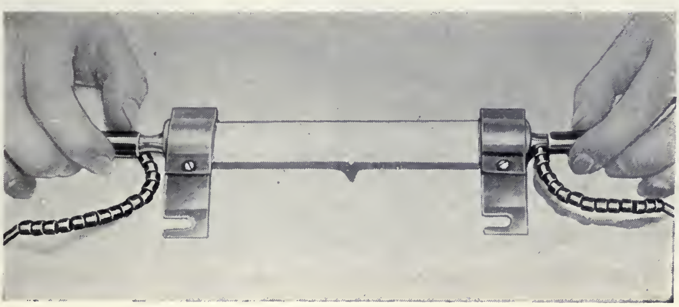

FIG. 233.—Quartz burner with activated electrode. (Courtesy of the Hanovia Chemical and Manufacturing Company.)

vapor arc in the form of a cord is produced. The new hot mercury arc operates equally well in any position and can be started at the snap of a switch instead of the uncertain "rocking" of the older burners; it also makes possible a more efficient conversion of electrical energy into ultraviolet light and the tubes are less heavy and less likely to be broken. The spectral energy distribution is similar to all other hot high pressure quartz mercury arcs.

The emission of the hot quartz mercury lamp contains very little short infrared radiation, a fairly large amount of the violet end of the visible spectrum and a large amount of ultraviolet; about 6 per cent of the total radiation is of wave lengths shorter than 2900 Angstroms, entirely absent in sunlight. There is considerable difference between this type of radiation and that of the sun. The spectrogram of the mercury arc consists of a series of spectral lines superimposed on a faint continuous spectrum. (See Frontispiece.) The quartz tube and the hood emit a low temperature, long-wave radiation.

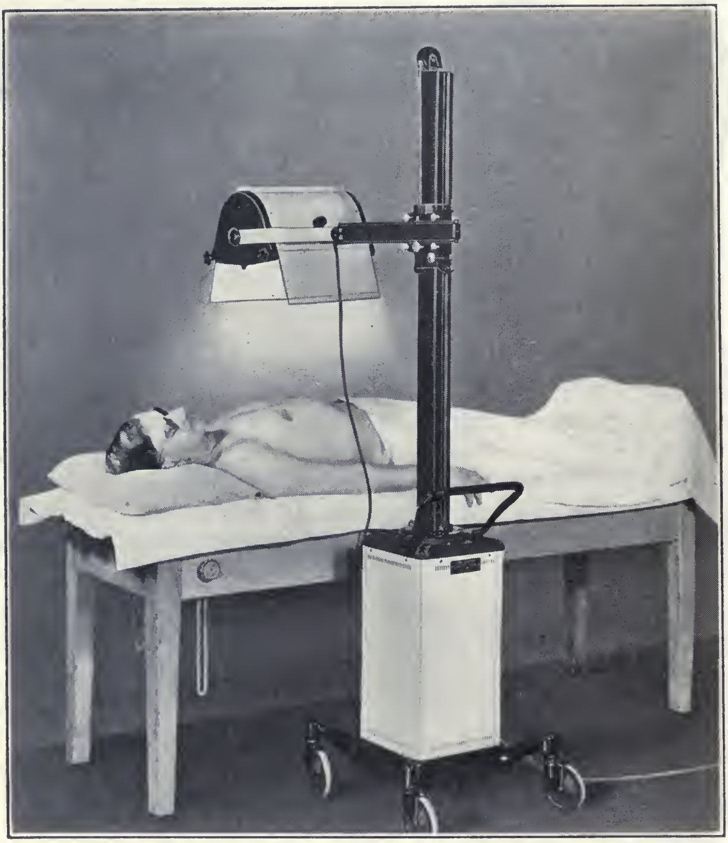

Fig. 234.—Hot quartz mercury lamp. (Courtesy of General Electric Co.)

Quartz burners slowly deteriorate with use, due to the fact that the quartz tube decreases in transparency and does not transmit as much of the light as before. The decrease of intensity affects all portions of the spectrum in nearly equal measure. The greatest decrease occurs during the first hundred hours of operation, and it is estimated that after that period the ultraviolet intensity is about 80 per cent of the original one. After one thousand hours the total intensity of radiation is from two-thirds to one-half of the lamps when new, provided that the lamps operate on the same voltage and amperage. Erythema tests should be applied periodically to check up efficiency of the burner. The ultraviolet energy output can also be physically measured from time to time.

The burners and lamps illustrated heretofore serve chiefly for general irradiation and being kept at a considerable distance from the body, the air circulating under their hood is sufficient to keep the burners from overheating; hence their designation as "air-cooled" lamps. Special mercury vapor lamps, specially designed for local treatment have been earlier known as "water-cooled" or Kromeyer lamps. In these the burner is surrounded by a water jacket with inflow and outflow tubes for cold water and has a quartz window at one side for the transmission of radiation from which the heat rays have been absorbed. These somewhat cumbersome and expensive lamps have been recently superseded by an air-cooled local ultraviolet lamp (Aero-Kromeyer), which eliminates the water-circulation system; it enables exposure of an area approximately 1½ inches in diameter at close approximation. Suitably shaped quartz rods can be attached to the "windows" of both forms of lamps, enabling the conduction of the rays inside of any mucous orifice, sinus or sluggishly healing wound cavity. Ultraviolet radiation will travel along these rods even when they are bent at an angle and then pass out at the end in a direct beam. It does not radiate along the sides of the rods.

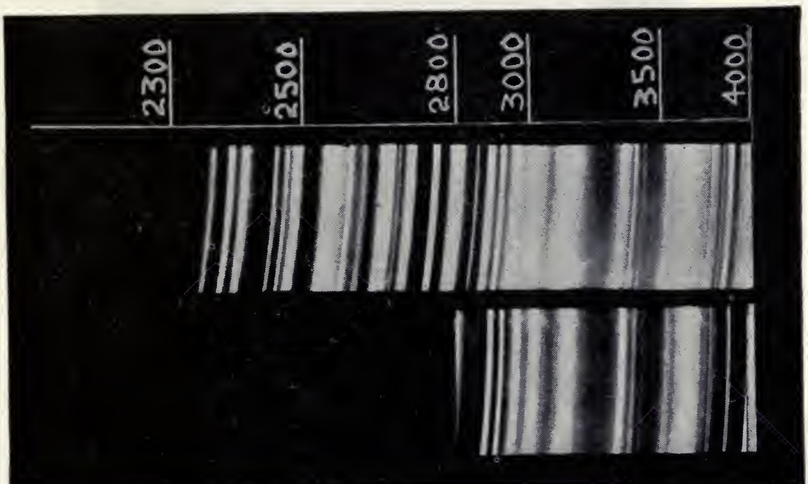

FIG. 235.—Spectrum of quartz mercury arc through Corex-D glass. Upper photograph shows full spectrum; lower shows only radiation of longer wave lengths than 2800 A°, all short waves having been filtered out.

The simplicity of handling and upkeep has made the hot quartz lamps the most widely used source of artificial light. They require comparatively little current; any other source of ultraviolet energy can produce the same intensity of radiation only by the expenditure of four or more times the electrical energy. With suitable "filters" various parts of their spectral emissions can be utilized. (Figs. 208 and 235.)

Cold Quartz Lamps.—In these lamps a narrow quartz tube containing mercury and neon gas, resembling the old time Geissler tube, becomes illuminated by an electrical current of high voltage. A transformer steps up the alternating current supply to about 2500 volts; the amperage and vapor pressure in the glow tube is very low; there is very little current consumption and consequently the tube remains cold and can be readily approached to the body or inserted in orifices. The full energy emission of these lamps is present within a minute and it remains extremely constant.

The spectral emission of cold quartz lamps consists of about 95 per cent in the line of 2537, in the short ultraviolet field. (See Frontispiece.) This ultraviolet band has enough penetrating power through the epidermis to cause biological and therapeutic effects; it also is antirachitic in rats, as are all radiations around 2500 Angstrom units. It produces erythema without much pigmentation or blistering. (Bachem.[3])

Cold quartz lamp generators come in two models: general body radiation lamps consisting of quartz tube in the form of a hexagonal grid mounted on a large aluminum reflector and supported on a stand and an orificial lamp, consisting of a holder of variously shaped rods for introduction in body orifices—such as the mouth, vagina, urethra and rectum. These orificial tubes emit rays from all sides and not only at their tip.

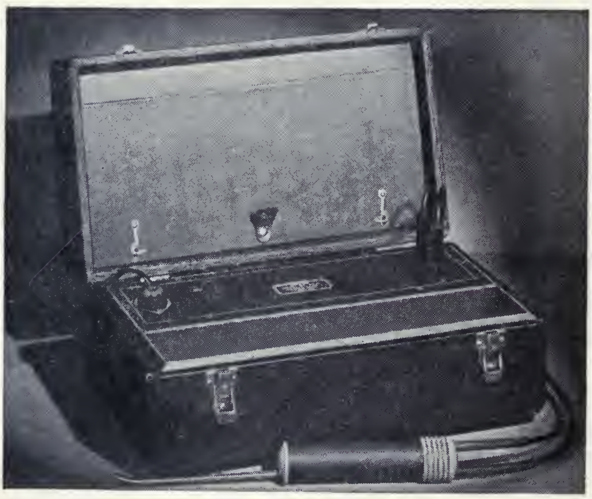

Fig. 236.—Low-pressure cold quartz lamp for local application. (Courtesy of the Hanovia Chemical and Manufacturing Company.)

The prevalence of bactericidal radiation from cold quartz generators points to their usefulness in superficial infections of the skin as well as of mucous membranes; also in some skin conditions. Coblentz[6] has expressed doubt whether in spite of its erythemogenic efficiency this type of lamp is suitable for general body irradiation. Although the lamp has been on the market for a number of years, no reports in the literature have appeared about its clinical usefulness for general body treatment.

Low-pressure Mercury Arcs.—In these lamps a bulb of quartz or other special glass contains a trace of mercury; an electric circuit heats up a tungsten filament and then two electrodes between them which an arc of mercury vapor forms, causing a glow which fills the entire bulb. These lamps come in two general types.

The Thin Window Mercury Glow Lamp.—In a glass bulb an indrawn thin bubble forms an extremely thin window which permits the passage of ultraviolet radiation down to 1800 A.U. which are not transmitted through the glass of ordinary thickness, and which are filtered out by the water in water-cooled lamps. A tungsten filament between two electrodes is heated by an independent circuit; in a few seconds a mercury arc forms between these two electrodes from the traces of mercury in the bulb. The lamp operates at 2 amperes at 16 volts and a special reactance (step-down transformer) serves to reduce the voltage of the A.C. supply current. On account of the relatively low temperature, the lamp can be brought in close approximation to the skin and serves for conditions amenable to local ultraviolet irradiation.

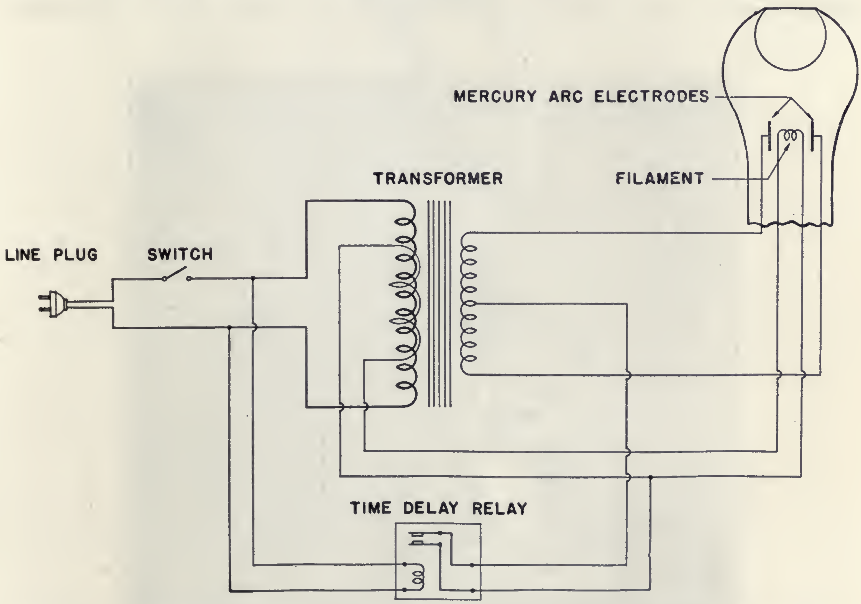

FIG. 237.—Diagram of thin-window lamp. (Courtesy of the Westinghouse *X*-Ray Corp.)

The relative energy distribution of the thin window lamp consists of 55 per cent ultraviolet, chiefly in the region of 2537 Angstroms, 10 per cent visible and 35 per cent infrared; this is therefore similar to that of the cold quartz units. The author[5] has made extensive clinical tests with this lamp and found that in the average skin an application for five minutes of close contact causes an erythema lasting five to ten days, which does not result in either peeling or blistering. A ten minute exposure is followed only by slight pigmentation. Laboratory studies show that it is possible to get a sterile culture from the surface of the skin after five minutes exposure. Clinical results were reported with the thin window lamp by the author and others in: (1) pyogenic infections of the skin; (2) fungous and parasitic affections of the skin, and (3) sluggish ulcers and wounds. This type of lamp has been further developed for air sterilizing. (See end of Chapter.)

Mercury Arcs in Corex.—In these lamps an ultraviolet transmitting Corex D or quartz bulb similar in shape to the ordinary electric light bulb contains a tungsten filament of V-shape and on top of this two tungsten electrodes. There is a drop of mercury in the bulb, and after the heating of the filament the vaporized mercury forms an arc between the tungsten electrodes.

The emission from the bulb is a combination of incandescent solid (tungsten) radiation from 3650 Angstroms throughout the visible and short infrared and mercury vapor radiation with strong lines between 2800 and 4050 Angstroms. The Corex D bulb absorbs all ultraviolet radiations shorter than 2800 Angstroms which are not present in sunlight. These lamps serve principally for home use as a source of radiation similar to sunlight. They come in two sizes: the S-1 type tulb at a distance of 30 inches produces the same ultraviolet effectiveness as midday, midsummer sunlight, while the smaller S-2 type bulb has the same effect at 24 inches.

FIG. 238.—Contact treatment by thin-window lamp.

Ten to fifteen minutes exposure at these distances will mildly sunburn the average person.

The bulbs of these lamps do not operate directly on the house current, but must be placed in a special fixture with a transformer; for this reason they are activated only by an alternating current supply. They are useful devices for home treatment under competent medical supervision.

Electrodeless Highfrequency Induction Lamps.—In these lamps a mercury glow is formed by the inductive effect of a high voltage circuit surrounding an evacuated quartz bulb containing a tiny drop of mercury. (Fig. 239.) A small induction coil is placed on the outside of a round bulb and is connected to the transformer of a diathermy machine, as an attachment to which this lamp serves. A potential of 5000 volts from the secondary brings the vapor of the mercury in the bulb to full luminescence within thirty seconds.

The special energy emission of this lamp is essentially the same as that of the hot mercury arc lamp, and the only difference according to Coblentz[6] is the intrinsic brightness (flux-density) of the lamp. In the ordinary quartz mercury arc all radiant energy is concentrated in a luminous column less than 10 mm. in diameter, whereas in the electrodeless discharge the radiation spreads over the entire bulb, some 6 to 8 cm. in diameter. Bulbs of different transparency of glass can be made to transmit or absorb shorter waves. During treatment the bulb remains comparatively

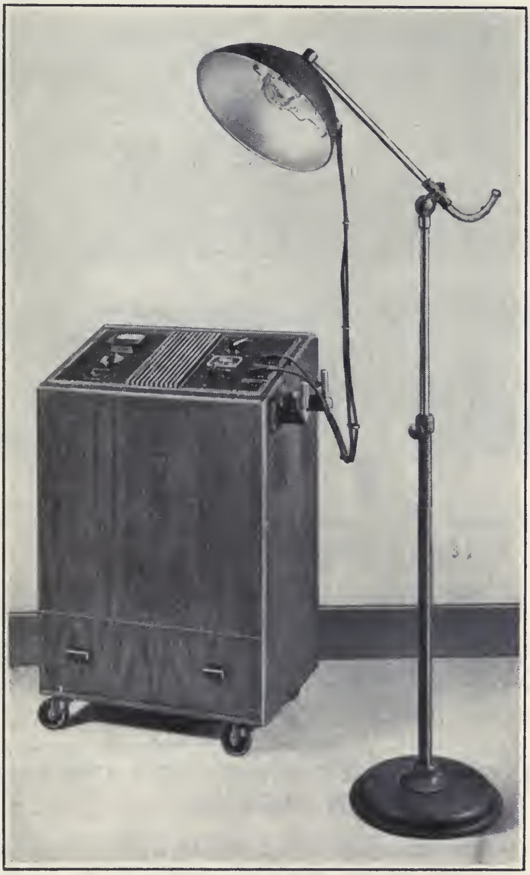

Fig. 239.—Electrodeless induction lamp, energized by short-wave diathermy machine. (Courtesy of the Lepel High Frequency Laboratories.)

cool and it is claimed that it retains its transparency to ultraviolet radiation in contrast to the gradual clouding of the hot quartz burners. The fact that there are no seals or electrodes protects the burner against loss of its vacuum.

Electrodeless quartz lamps can be furnished in the form of a general body lamp as illustrated, and in the form of a hand lamp for local application. The mounting of miniature quartz bulbs on the end of wired catheter tubes, enables the insertion of these sources of radiation into practically every orifice and cavity of the body, kidney, colon and stomach.

The combination of this lamp with a high-frequency apparatus enables saving of space in small offices. Some long-wave and short-wave diathermy units have been equipped with circuits to energize such electrodeless ultraviolet lamps.

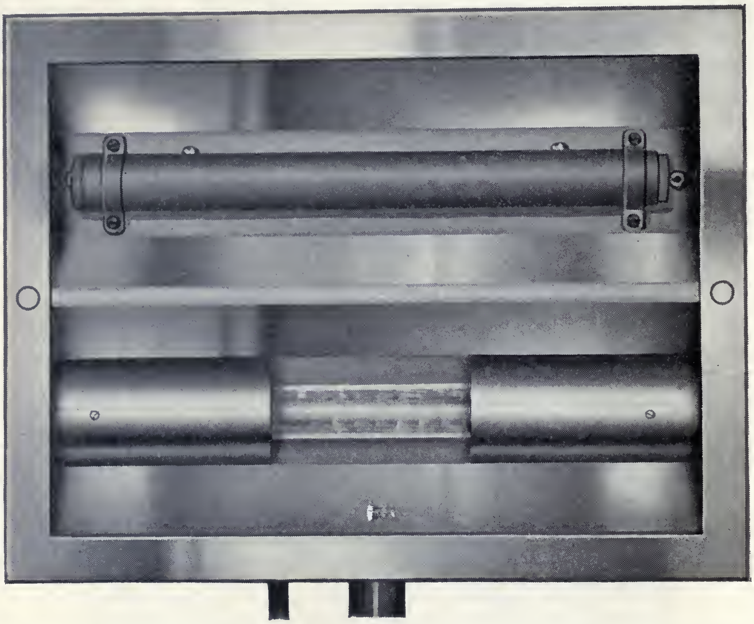

FIG. 240.—Combination hot quartz and infrared burner. (Courtesy of The Liebel-Flarsheim Company.)

Combination of Hot Quartz and Infrared Units.—A combination of the radiation of a hot quartz unit with an infrared one offers the advantage of the full range of the phototherapeutic spectrum when desired or the use of either component. The employment of one stand is an economic advantage especially in a small office. (Fig. 240.)

CHOICE OF ULTRAVIOLET GENERATORS AND STANDARDS OF EMISSION

It was pointed out repeatedly that the ideal situation would be to be able to select a radiant energy generator furnishing an efficient emission of a single wave length which has proved specific for a given pathological condition. According to present-day clinical practice, supported by the ruling of the Council on Physical Therapy[8] all generators emitting a sufficient intensity of sunburning (erythema producing) radiation are acceptable for ultraviolet therapy. Our present ultraviolet generators generally furnish combinations of the three principal groups of radiations: (1) infrared, luminous and full range of ultraviolet radiation, as represented by the modern carbon arc lamp; (2) luminous and a full range of ultraviolet radiation as represented by the hot quartz and electrodeless induction lamp; (3) an almost monochromatic radiation of short ultraviolet as represented by the cold quartz lamp, the thin window mercury glow lamp, and the recent air-sterilizing units. Table 43 shows the principal sources of phototherapeutic radiation and the spectral range of their emissions.

In considering the available ultraviolet generators in treatment of a specific case the first question arising is whether heat radiation in addition to ultraviolet is desirable or not. Clinical experience shows that heat in itself is beneficial in rheumatoid conditions and in joint and glandular tuberculosis; in these conditions carbon arc irradiation may be more preferable, therefore, or an infrared generator may be employed in addition to the ultraviolet source. On the other hand an excess of heat radiation is often undesirable in pulmonary or intestinal tuberculosis and in rickets, hence the preference of a radiation mainly restricted to ultraviolet in these conditions. In superficial infections of the skin and mucous membranes a generator furnishing only the shorter bactericidal range of ultraviolet radiation is preferable. The present range of generators enables a fairly wide selection according to these postulates, but there still exists need for further controlled clinical work.

Standards of Emission.—The effectiveness of ultraviolet generators is judged by the Council on Physical Therapy[8] on the basis of the erythemal reaction. The specifications of minimum intensity are based on a comfortable and convenient operating distance (24 inches, or 61 cm.) from the front edge of the reflector, at which distance the exposure can be made without burning the skin by coming in contact with the burner or by the infrared rays. The ultraviolet intensity of the lamp shall be such that the time of exposure to produce a minimum perceptible erythema (one that disappears in less than twenty-four hours) will not be longer than fifteen minutes for a therapeutic lamp and sixty minutes for so-called sun-lamps.

TABLE 44.—ERYTHEMOGENIC EQUIVALENT OF ULTRAVIOLET RADIATION REQUIRED TO PRODUCE ERYTHEMA (COBLENTZ[6])

Source	Ultraviolet intensity in microwatts per square centimeter
Sun: Midday, midsummer, midlatitude, sea level	91
Carbon arc: Blue flame, cored carbon, in reflector, no window	48
Carbon arc: Glass window, opaque to 2800 Angstroms and shorter (estimated)	90
Mercury arc: General Electric Mazda, type S-1 lamp; high temperature arc in parallel with V-shaped tungsten filament	83
Mercury arc: General Electric Mazda, type S-2 lamp; similar to the S-1 lamp, but smaller; both in glass bulbs	93
Mercury arc: Types G-1 and G-5; low temperature, low voltage thermionic glow discharge; glass bulb	108
Mercury arc: High temperature, high vapor pressure, low voltage; quartz tube	58
Mercury arc: High-frequency electrodeless discharge; quartz bulb	60
Mercury arc: Low temperature, low vapor pressure, high voltage, "cold quartz," Geissler tube discharge	36

As the emission line of the mercury arc lamp of 2967 Angstroms has the highest efficiency in generating an erythema, 100 per cent, in comparison to all other wave lengths, this line appears suited as a natural standard for evaluating sources of heterogenous ultraviolet radiation. The Council has therefore adopted 20 microwatts per square centimeter of homogenous radiation of wave lengths 2967 Angstroms as the erythemal unit (E. U.) of dosage; that is, 1 E. U. = 20 microwatts per square centimeter of radiation of wave length 2967 Angstroms.[8] For home use the Council only accepts lamps which emit practically no ultraviolet radiation shorter than 2800 Angstrom units.

TECHNIQUE OF ULTRAVIOLET IRRADIATION

Administration.—In general irradiation the entire unclothed body is exposed, hence the treatment room should be warm and also well aired. It is advisable to provide an individual dressing gown or sheet for each patient which covers him until the actual exposure. The eyes of the patient as well as those of the operator should be protected by goggles. Ordinary leatherette goggles can be bought cheaply by the dozen, and individual goggles provided for each patient. In case of doubt as to the effectiveness of protection, goggles should be tested for ultraviolet transmission. In patients with a sensitive skin it may be well to cover the face by a thin towel at first; the genitalia should generally be covered by a loin cloth or a folded towel. A shield cut from heavy paper may protect the nipples. If the face is exposed it should not rest on a high support, as this would result in a more intense exposure because of the shorter distance from the lamp. (Fig. 234.)

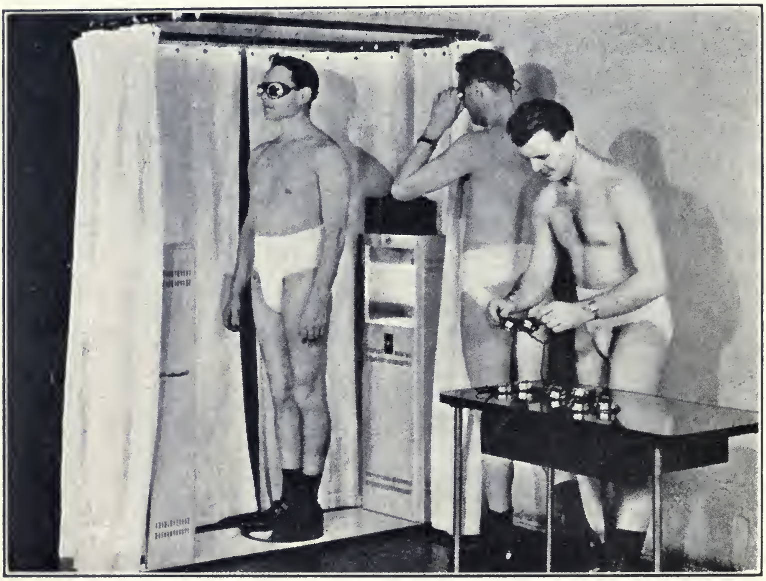

Fig. 241.—Solarium shower. (Courtesy of The Burdick Corporation)

Patients are usually treated in the recumbent position. The table or couch on which the patient rests should be a low one, allowing a ready variation of the distance from the lamp. Modern mercury and carbon arc vapor lamps now allow radiation at various angles instead of only from the horizontal or vertical position. The center part of the body should be placed in the direct line of radiation, but no old style hot quartz lamp should ever be placed directly over the patient's body.

The preliminary application of luminous heat from a large 1500-watt lamp is generally advisable, with the first few treatments with the mercury vapor lamp. Warming of the skin makes the patients feel more comfortable than if a very short exposure to the comparatively cold mercury vapor radiation is applied alone and will also accelerate the chemicobiological process following radiation. The duration of the heat radiation should be from ten to fifteen minutes and its length decreased as the length of the ultraviolet exposures is increased.

The carbon arc lamp is ready for use as soon as it is lit and preliminary heat radiation is not necessary. With the hot mercury vapor lamp one must wait for two minutes or more according to the type of lamp, until the full output of radiation is developed. Patients experience no sensation except that of the slight warmth during treatment with the mercury arc and more intense heat when the carbon arc is used.

A time-clock should always be used to measure the time of exposure. As general radiation is usually equally divided between the front and back, the patient is instructed to turn over with the first signal and the clock is then set again for the second half of the treatment. At the end of the treatment with old style burners the hood is closed and the lamp is kept burning if there are other treatments to follow. This keeps the intensity of radiation on an equal level. All other lamps should be switched off to save current. At the finish of treatment, patients are ready to leave the office as soon as dressed.

Dosage.—In our present practice the erythemal response of the individual patient serves as a guide of dosage. For general irradiation the first dose is usually one which just about causes a first degree erythema. The principal factors in dosage are distance of the burner and length of exposure. These will vary according to the efficiency of the apparatus, the individual sensitivity of the patient and the progress of treatment. As patients are irradiated with ultraviolet they develop an increasing tolerance enabling them to stand successively larger doses.

Further combined clinical and laboratory research may determine what wave length and intensity of radiation per unit of body area is necessary for therapeutic effect in different pathological conditions. Gerstenberger and Hartman[10] demonstrated the possibility of such definite dosage, comparable with dosages in drug therapy. They found that exposure from a mercury vapor lamp in doses of erythema units, determined by a definite scale, given once a week is sufficient in the cure and prevention of rickets and rachitic spasmophilia.

(*a*) *Efficiency of Ultraviolet Lamps.*—Various types of apparatus produce a first degree erythema at various distances and exposure times. The efficiency of one's apparatus—chiefly depending on the condition of the burner in hot quartz lamps—should be checked up from time to time by simple skin tests; the same tests serve also to test individual sensitiveness of patients.

A simple method for testing is the following: The upper arm is covered by a shield made from a large manila envelope, or by a sleeve made of black cloth in which five small holes are cut. Under this shield is placed a shutter strip of the same material. The forearm and the face are protected by a towel. The arm is placed at 30 inches directly under the lamp burning at full strength. The shutter strip is withdrawn from the first opening, two minutes later it is withdrawn from the second. One minute later, it is withdrawn from the third opening; thirty seconds later, from the fourth; fifteen seconds later from the fifth and, after fifteen seconds more, the light is shut off. This results in a progressive period of total exposure for the various openings, ranging from fifteen seconds for the fifth opening to four minutes for the first. (Fig. 242.) Within a few hours there should be an erythema visible over one or more of the areas exposed. The exposure time of the area which becomes pale next morning shows a first degree erythema dose and indicates the average dosage for it at 30 inches.

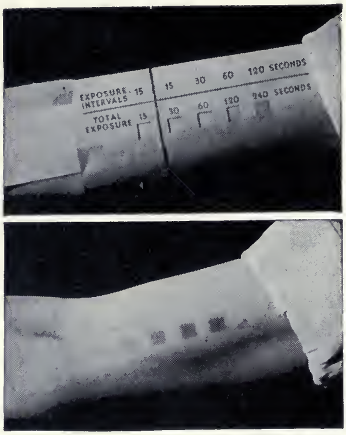

Fig. 242.—Testing for lamp efficiency or ultraviolet sensitivity. (Courtesy of the National Carbon Company.)

(*b*) *The Distance From the Burner.*—It is advisable to start treatment at a standard skin-burner distance of 30 inches and with the exposure time calculated to give a first-degree erythema; on subsequent treatments, one should not change the distance, but gradually increase the exposure time. In keeping the factor of distance constant there is less chance of confusion or error. When the maximum time of exposure, say fifteen minutes with the hot quartz lamp has been reached one can begin to change the skin-burner distance. This can be lowered 2 inches at each successive treatment, until the lamp is at 18 inches. A distance of less than 15 inches is not safe for general irradiation on account of the possibility of a heat burn from the infrared emissions of the hot quartz burner. There is also more loss due to the angulation of radiation if the lamp is brought too close to the body. With carbon arcs it is not advisable to bring the burner closer to the body than 30 inches, except for local treatments, on account of the possibility of a heat burn.

According to the law of inverse square, moving an object to double the distance from a source of radiation cuts the intensity of radiation to one-quarter; this law does not apply quite strictly to radiation sources which are not a point, but a more extended surface. Anderson's table[1] shows the relative intensity of uniform time exposures given at different distances:

Table 45.—Relative Radiation Intensity at Different Distances

Distance (inches) . . .	40	31	26	22	20	17	14	12	10
Proportionate dose . . .	1	1½	2	2½	3	4	5	7	9

Contrary to previous misconception as Krusen[17] points out the shorter distance from the burner to the skin does not increase the proportion of short ultraviolet rays reaching the skin because the air absorption of other rays of the therapeutic range is negligible at the usual treatment distances.

(c) *Length of Exposure.*—The time necessary to produce a first-degree erythema in a patient with average susceptibility at a given distance is different for each type of lamp. With the average hot quartz lamp one minute at 30 inches is usually sufficient.

As in succeeding treatments a gradual tolerance to radiation develops and the t me of exposure as a rule can be safely increased by two minutes each time. For general tonic treatment by the hot quartz lamp in the average patient the second exposure may be given next day, and the time of exposure should be three minutes; further increase of two minutes is made at each successive treatment so that, at the end of two weeks with treatments two days apart, an exposure of fifteen minutes is reached. All these treatments are administered at first at the standard distance of 30 inches.

A scheme of exposure for the average "tonic" treatment by a hot quartz lamp with a fairly new burner is given in Table 46.

TABLE 46.—SCHEME OF EXPOSURE WITH HOT QUARTZ LAMP

Treatment No.	Distance skin-burner	Time of exposure
1	30	1
2	30	3
3	30	5
4	30	7
5	30	9
6	30	11
7	30	13
8	30	15
9	28	15
10	26	15
11	24	15
12	22	15

All dosage and distances mentioned must be subject to modification in accordance with the individual susceptibility and the age of the patient and the condition treated. In cases of severe anemia and debility it may be advisable never to give more than two to three minutes' daily exposure from the standard distance. In surgical tuberculosis and in other conditions where the reactive capacity of the organism is well preserved, one may increase time and distance more rapidly than in the scheme indicated and bring about quick pigmentation. With second-degree erythema production however one must space treatments carefully so as to avoid too intense reactions in rapid succession.

If the treatment is interrupted at any time and later resumed the time of exposures must be estimated according to the length of time that has elapsed since the last exposure. It has been estimated that resistance against successive radiation increases to a maximum in about seven days after treatment, remains the same until about the twentieth day and then rapidly decreases during the next twenty days.

(d) *Area of Body Exposed.*—In order to play safe in the occasional instances of unsuspected individual sensitiveness the rule holds to divide the time calculated for a first-degree erythema dose between the front and back of the body and then apply further radiation in the same way. In patients in whom for some reason only one surface of the body can be exposed—immobilization in cast, extensive dressings, etc.—one-half of the usual treatment time should be given at first and then carefully increased.

An irritative dose should never be applied except to small areas, whereas a tonic dose should be applied to as much of the body surface as possible.

Different body areas react differently to radiation; those with a thick horny layer are the least sensitive. According to Bach the most sensitive are the face, the chest, the abdomen, back and sacral region, next come the arms and legs and least sensitive are the hands and feet. Flexor surfaces are generally more sensitive than extensor surfaces.

(*e*) *Frequency of Irradiation.*—No erythema dose should be repeated until the reaction from the previous exposure—if any—has completely subsided. With patients treated in hospitals or at home daily treatments may be given at first; patients coming to the office may be treated every other day.

A course of twelve treatments administered to ambulatory patients during four weeks at a rate of three treatments per week is usually sufficient for general tonic purposes, provided that it is accompanied by satisfactory clinical improvement. After a full course of irradiation it may be advisable to continue irradiation once or twice a week, or stop altogether. In cases of tuberculosis treatment may be continued for longer periods.

Mayer[20] states that overdosage through too frequent irradiation may interfere with a favorable result. In irradiation for prevention of colds weekly or biweekly dosages of only ten minutes (Maughan[19]) have been effective in cutting down the incidence of colds as much as 40 per cent. This is an important argument against over-use of self-prescribed and self-administered ultraviolet irradiations by lay people which is usually overdone in both duration and frequency.

Individual Sensitivity.—Blondes are from 40 to 170 per cent more sensitive than brunettes and men 20 per cent more sensitive than women. Persons between twenty and fifty are more sensitive than those younger or older. The minimal dose within toleration is best determined by preliminary skin testing, for if an overdose is given burns or itching may develop. As a matter of safe routine it is advisable to administer to children and aged people only one-half, to women about three-quarters, and to blondes and red-haired persons about one-third to one-quarter of the average dose.

People with tanned skins and dark complexions can stand an initial dose larger than the average. People with inborn sensitivity do usually know about their poor tolerance to sunlight.

Temporarily increased sensitivity to radiation may occur after any procedures which enhance the circulation of the skin, such as an incandescent-light bath, hot bath, massage given before irradiation. Alcoholic subjects, patients with long-standing malaria or syphilis may show increased reaction, likewise persons sensitized by any of the agents enumerated in Chapter XVII.

Dangers in General Ultraviolet Irradiation.—When applying radiation from any source it is important to keep in mind not only a safe dosage but also the possibility of abnormal sensitivity of the patient.

Burns or other injuries may occur in connection with artificial light treatment on account of two groups of cases: (1) hypersensitivity, either inborn or due to causes predisposing pathological conditions. These causes have already been discussed in this chapter as well as in Chapter XVII. (2) Overdose of radiation and other improper handling of apparatus.

Overdose from any light source may result either from an excessive single exposure or from exposures repeated over too long a period. The immediate visible effect of a single over-exposure may be an erythema due to the infrared (heat) rays; exceptionally there may be immediate blister formation. Ordinarily the erythema disappears in an hour or so and in a few hours the effect of the ultraviolet rays begins to show. A dermatitis—skin burn—of varying intensity and extent develops. The main features and treatment of these burns have been presented in the chapter on electrical injuries. The longest wave length that can produce a burn is about 3150 Angstroms. In addition to burns, there may occur general symptoms: headache, nausea, or high fever and irregular heart action. Such reactions occurred when patients fell asleep under an ultraviolet lamp or when they insisted to find out how much irradiation they could stand. The severe general effects are due to the flooding of the blood stream with the destroyed protein substances, a severe "protein shock." It is, of course, well known that over-doses of natural sunlight can bring about similar severe reactions. Humphris[13] reports a fatal case of a woman, aged forty-eight years, who took the "sunlight treatment" on her own, and who after the second treatment became ill and showed two burns of brick-red color on the left leg, and the lower back. A few days later she developed fever, diarrhea, hematemesis, passed dark blood and died after twelve days. Postmortem examination showed gastric and duodenal ulceration and the medical men present agreed that these were the result of the burn.

In the course of ordinary treatments such severe reactions are very rare, because fortunately a margin of safety as great as 50 per cent exists (Mayer[20]) and nature reacts much less severely to overdosage from light than to overdosage from roentgen-rays.

Improper Handling of Apparatus relates usually to the home use of ultraviolet. In a fatal accident reported from England a young man was electrocuted while touching an ultraviolet lamp which he lit in a bathroom. It was found that there were about one-half dozen ways in which electrical short-circuiting could have happened with that flimsy make of lamp. Of course the use of any electrical equipment in a bathroom is dangerous.

There is some risk in placing the old style hot quartz burner directly over the patient because it might suddenly crack. The modern "hot quartz" burner which contains no fluid mercury is free from this danger.

Neglecting to protect the eyes against irradiation may result in various degrees of inflammation as described in Chapter XVII. Painful conjunctivitis in both patients and careless operators has been reported. Lear[18] described a general inflammation of the conjunctiva, cornea, iris and the lens, known as photoöphthalmia. One of his cases occurred in a man who had several "sun ray" treatments in a Y. M. C. A. gymnasium, with his eyes unprotected.

Dangers of Home Treatment.—A survey of the possible ill-effects of self-prescribed and self-administered treatments by the laity was made by a committee of the Medical Society of the County of New York[14] consisting of clinicians, pediatrists, orthopædic surgeons, dermatologists and physical therapists. There were reported aggravation of cases of quiescent pulmonary tuberculosis; aggravation of various skin conditions, such as eczema, psoriasis, lupus erythematosus and numerous instances of burns of varying severity, including dermatitis solaris lasting many months; a number of cases of conjunctivitis, due to careless and unskilled exposure; in children a decrease of hemoglobin count when ultraviolet irradiations were continued for a period of months; also some cases of immediate febrile reactions. The committee expressed the practically unanimous opinion of the medical profession that, with so many injurious effects already on record, the prevailing practice of uncontrolled self-treatment by the laity is harmful.

In spite of the vigorous commercial propaganda in favor of home treatment, there are comparatively few instances in which there is real indication for the use of powerful sources of ultraviolet radiation in the patient's home. The danger of over-exposure, of careless handling of apparatus and of the indefinite continuation of radiations are all valid reasons against home treatments, without the immediate and continuous supervision of a competent physician.

The Council on Physical Therapy[8] will not include sun lamps in its list of accepted devices if they emit radiations shorter than 2800 Angstroms without using a Corex D filter and if they are recommended for use without supervision of a physician.

SPECIAL TECHNIQUES OF ULTRAVIOLET IRRADIATION

Local Irradiation.—Local irradiation to a circumscribed area of the skin from the usual types of lamps does not involve any new principle nor are any additional devices necessary. One may use any type of body lamp by simply covering the area not to be treated and radiate only the affected part. It is important that such areas be thoroughly cleansed from dead cells, scales and greasy material which interfere with penetration.

The dosage in local irradiation will depend on the condition to be treated. Burns, clean granulating tissue should receive mild erythema dosage; this can be repeated daily. Suppurating areas or those with old skin lesions usually do better under intensive dosage. A four-minute irradiation at 15 inches distance from a new air-cooled mercury vapor lamp will produce a marked dermatitis (third degree erythema). Such a dose can be repeated only every four or five days. In erysipelas very intense dosage ten to twenty times the erythema dosage at fairly close range has been recommended. (See Chapter on skin conditions.)

For local irradiation at close range and for cavities the various types of local irradiation units may be employed. Special applicators serve to reach locations which cannot be subjected to direct radiation. In determining dosage one must remember the normal mucous membranes tolerate about twice the dosage of the average skin; the nasal mucosa tolerates several times more. When applying an intensive dose to a mucosa, the surrounding skin must be protected by some greasy substance against over-exposure.

The Finsen Treatment.—The original Finsen apparatus consists of a metal stand, as illustrated. In its upper part an arc is struck between two carbon electrodes by a direct current of 55 volts and 50 amperes. This powerful light is radiated in four directions through four telescopes containing quartz lenses, running water between the lenses absorbs most of the heat rays. The remaining luminous and ultraviolet rays are applied to the skin through a compressor consisting of two rock-crystal lenses; a flow of cold water between these layers eliminates the last portions of heat rays while pressure of the compressor renders the part anemic and permits deeper penetration of the radiation.

In the Finsen treatment only an area of about the size of a dime is irradiated each time, for sixty to seventy minutes. The result of such intense local raying is a severe local inflammatory reaction, usually leading to a blister over the area exposed. It takes about three days for the full development of this reaction and about fourteen days for its retrogression. In the later stages there forms a smooth scar over this area and this cosmetic result is hailed as the chief advantage of the Finsen treatment.

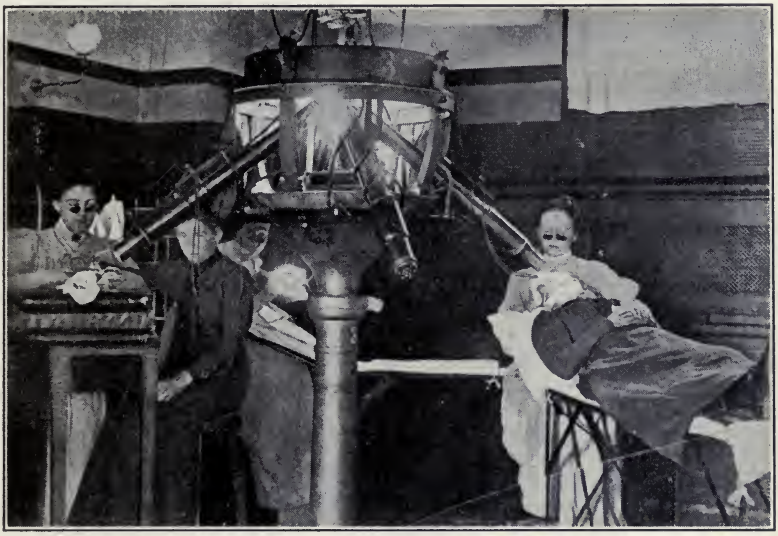

FIG. 243.—The Finsen treatment.

For the treatment of one patient at a time the late Reyn has constructed a small 20-ampere lamp with the carbons in an angular position; the rays of this device radiate only in the direction of the single telescope and cooling apparatus.

The Finsen treatment started as a purely local treatment. Later general carbon arc irradiations were added alternating with local treatment.

Best results by Finsen treatment are seen in lupus vulgaris and lupus erythematosus. In various forms of eczema and acne the treatment is claimed to be superior to other methods. Laryngeal tuberculosis, tuberculous glands, Roentgen-ray and radium burns have also been considerably benefited. In the United States the Finsen treatment has found very little employment, partly because lupus vulgaris cases are not as frequent as they are in Northern Europe and partly because the treatment is tedious and expensive.

Ultraviolet Blood Irradiation.—After clinical use for over five years, spectacular results are claimed for Miley, Barrett,[4] Rebbeck[23] for hemo-irradiation by ultraviolet in certain conditions and it is stated that there were no harmful effects on blood cells or other untoward reactions. For this procedure a special apparatus has been constructed by Knott. It

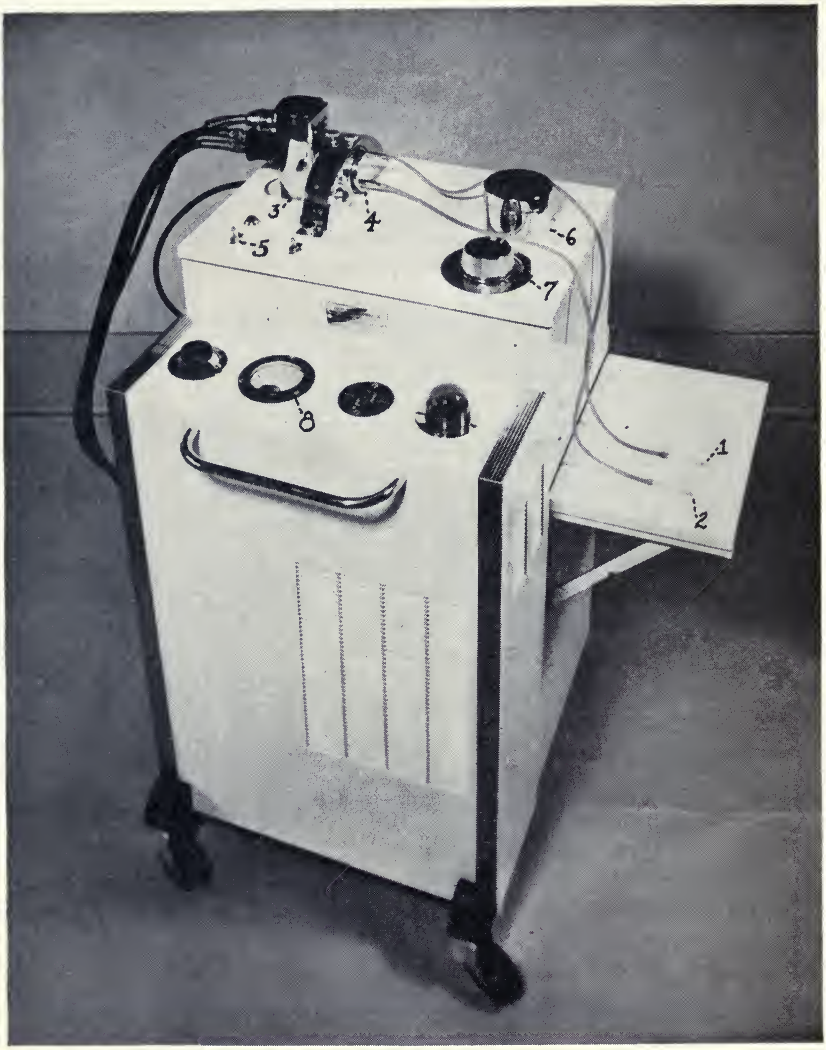

FIG. 244.—Hemo-irradiation outfit. Hemo-irradiator. *1*, glass-tipped adapter for suction or withdrawal end of rubber tubing system; *2*, glass-tipped adapter for intravenous or injection end of system fitted to needle in patient's vein. Citrated blood that has just passed through irradiation chamber (*4*) is returned to venous circulation through this adapter. *3*, water-cooled, mercury-quartz burner, source of high-intensity ultraviolet energy used in irradiating blood; *4*, Knott irradiation chamber with quartz window held in contact with mercury-quartz burner. Blood is passed through this chamber, its time of exposure being automatically adjusted. *5*, starting switch; *6*, synchronized transfusion pump; *7*, dial regulating rate of flow and time of exposure; *8*, voltmeter. (Courtesy of Dr. G. Miley.)

consists of a circular irradiation chamber 2 inches in diameter and 1 inch deep, against which a water-cooled-mercury quartz burner is held. Transfusion tubings are attached to two outlets from the chamber. The formula

A = KW determines the amount of blood to be withdrawn, with A the amount in cubic centimeters, K a constant (1.5) and W the weight expressed in pounds. The average blood withdrawn is 225 cc. The venous blood withdrawn is citrated (1 part 2.5 per cent sodium citrate to 5 parts of blood) and immediately returned to the patient through the hemo-irradiator to the vein from which it was withdrawn. The time of exposure is considered the time required for the passage of 1 cc. blood through the chamber while exposed to ultraviolet irradiation. An automatic transfusion pump and a mechanism for controlling the flow of blood and consequently the irradiation time is part of the apparatus.

The biophysical effects attributed to this procedure are: attenuation and destruction of bacteria, inactivation of toxins and viruses, increased absorption of oxygen by the blood and increase in general resistance to infection.

Good results are reported by Miley[22] in 103 cases of acute pyogenic infection, including staphylococcemias (septic abortion, puerperal sepsis); the treatment in successful cases resulted in reduction of high fever and toxic symptoms in twenty-four to thirty-six hours; in 13 cases of acute thrombophlebitis, most of which failed to respond to routine treatment by heat, bed rest, elevation and also sulfonamides; there was rapid disappearance of pain and tenderness after a single blood irradiation; 80 patients with intractable bronchial asthma exhibited marked improvement. Rebbeck[23] also reported on successful treatment of a series of cases of puerperal sepsis and postabortional sepsis.

It is interesting to note that while the three clinicians here mentioned have for over five years reported favorable results with hemo-irradiation, other clinicians have made no reports whatsoever on this procedure. There seems to be need for clearing up two doubtful points in conjunction with hemo-irradiation. One is an explanation why irradiation of such a small amount of blood exerts such a profound effect on the entire blood. The other is answering the contention made that similar results can be achieved in some conditions by using autotransfusion alone without irradiation.

AIR STERILIZATION

Following the path-finding studies of Hart,[12] Wells,[26] and others it has been well established that ultraviolet radiation can destroy air-borne microörganisms and that such radiation can be used to prevent air-borne infection in operating rooms[16] and thus diminish the incidence of infection in clean wounds; such radiation can also be employed to prevent cross-infection in contagious wards[11] and the spread of respiratory infections in offices and public rooms.

The spectral band of 2650 appears to exert maximal bactericidal action. (Coblentz.[7]) In the most readily obtainable sources of germicidal radiation the emission line of 2537 dominates the spectrum and is therefore taken as the standard of homogeneous radiation for evaluating the output of germicidal radiation. From experimental data it appears that the minimal radiant flux of wave length 2537 A° at a distance of 1 M. from the lamp should not be less than 100 microwatts per sq. cm.

Physics of Germicidal Lamps.—For air sanitation and for others sterilization purposes mercury discharge lamps are universally used at present.

The low pressure quartz discharge lamp emits 93 to 95 per cent of its ultraviolet energy between 2500 and 2600 A°, near the peak of bactericidal efficiency. They can be made of high transmission glass which allows the 2537 A° rays to be given off but absorbs the shorter ozone producing rays in the neighborhood of 2000 A°. A lamp used for disinfecting purposes is a single unit and its usual types consume about 15 watts, sometimes as much as 45 watts.

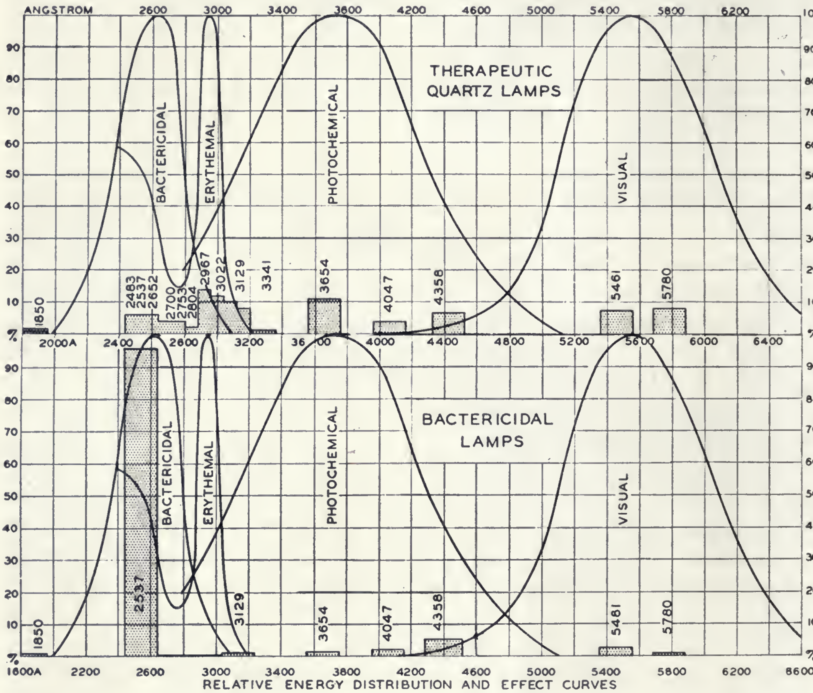

FIG. 245.—Relative energy distribution for equal electric inputs to hot quartz lamps and low-pressure bactericidal lamps with superimposed effect curves. (General Electric Co., Nela Park Division.)

Ultraviolet radiation of 2000 A° and shorter wave length converts some of the air around the lamp into ozone. When ozone is undesirable, the quartz burners are supplied with a filter jacket to filter out these short wave lengths.

When first installed, the radiant ultraviolet energy is considerably more intense than 20 microwatts per sq. cm. at 1 M., the minimum intensity for acceptance. As the lamps age, the intensity drops off rapidly at first and slower later. Under ordinary usage the lamps maintain the acceptable minimum intensity or above for the guaranteed period of 4000 hours of continuous operation. Users of the equipment are advised to test the lamps each month to determine that they are up to standard. Since the lamps burn at a characteristic color constantly, there is no way of determining whether they are emitting sufficient ultraviolet radiation except by testing them with an ultraviolet meter.

Discharge tubes of lamps should be kept clean, since dust would absorb appreciable amounts of ultraviolet radiation. This should be done by wiping them frequently with a clean cloth moistened with pure residue-free absolute alcohol, carbon tetrachloride or distilled water.

Acceptance of Germicidal Lamps.—The Council on Physical Therapy[9] limits acceptance to ultraviolet disinfecting lamps designed for installation in hospital nurseries, hospital wards and operating rooms. Satisfactory evidence is not available to warrant acceptance of ultraviolet lamps for disinfecting solids. In view of available evidence, ultraviolet radiation appears to be an uncertain means of sterilizing solid objects (drinking cups, combs, brushes, shaving utensils, toilet seats and shoes) even if irradiation of the whole surface is possible. Ultraviolet lamps for disinfecting purposes are not accepted for disinfecting air in schools, waiting rooms, public gathering places and large halls.

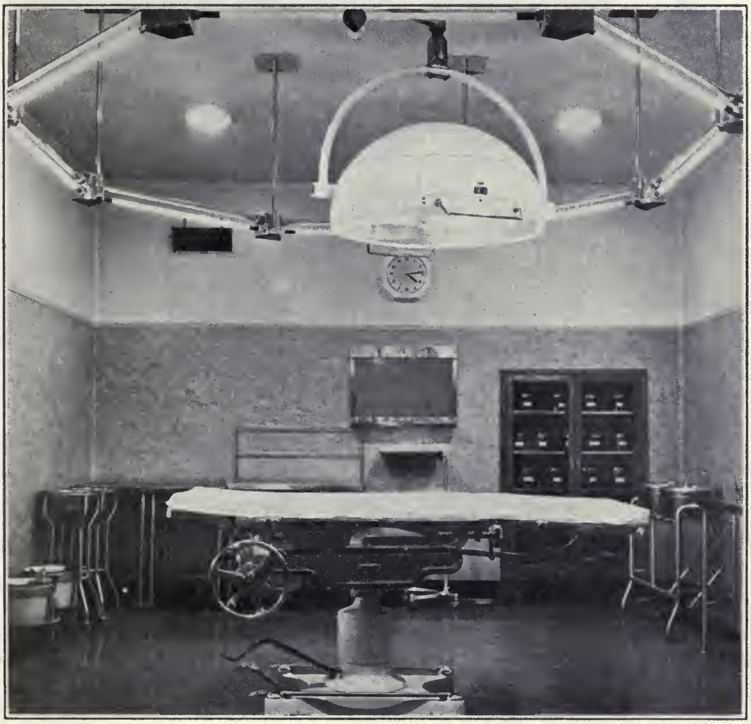

FIG. 246.—Sterilamps arranged in octagon form around an offset operating room lighting unit. This arrangement permits moving the lighting unit to any position without disturbing the ultraviolet radiation. (Courtesy of Westinghouse Electric & Manufacturing Company.)

The total amount of direct and scattered ultraviolet radiation incident on the occupants must be kept below the level that will produce conjunctivitis, erythema and any other (at present unforeseen) injurious effects from prolonged irradiation. This requirement may be met by suitable arrangements of the lamp fixtures and baffles and not by requiring the applicants to wear glasses and special covering of exposed parts normally uncovered. If the radiation is penetrating, *e. g.*, in the corridor of a hospital, care should be taken that attendants do not receive an exposure which will cause injury to skin or eyes, and particular attention should be taken to assure that the intensity of the space at eye level through which a transient may pass or tarry momentarily will not cause eye injury.

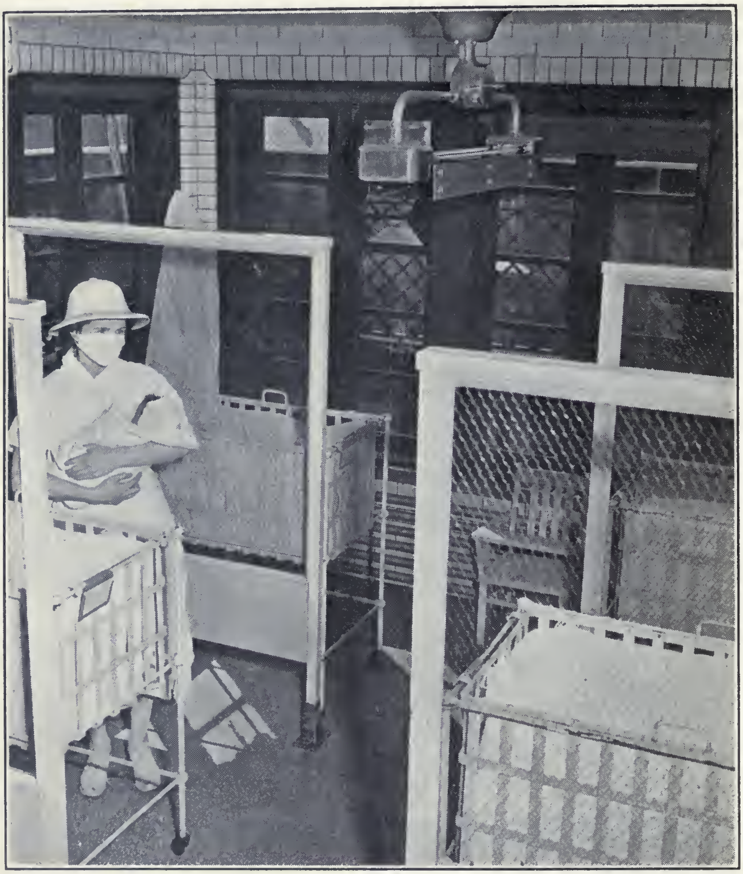

FIG. 247.—Nursery instalment of constant intensity ultraviolet unit equipped with shields to prevent the direct radiation reaching the cribs but allowing the ultraviolet rays to reach the aisles between cubicles and the entire upper portion of the room. This forms barriers against cross-infection. (Courtesy of Westinghouse Electric & Manufacturing Company.)

Practical Uses.—Practical installation of ultraviolet air sterilization may be grouped in one of three categories:[25] (1) rooms in which direct radiation is permissible because of absence or short duration of human occupancy, with suitable precautions to safeguard the eyes and skin of any occupants; (2) rooms in which indirect irradiation must, for practical reasons, be used; (3) air-circulating systems in which ultraviolet lamps may be installed in ducts or otherwise in the circulating system with or without recourse to supplemental irradiation in the rooms involved. The first is used in operating rooms, food storage spaces, bacteriology laboratories, food preparation rooms and for sanitation of air in a hospital room recently evacuated before installation of a new patient. The second is adaptable to hospital nurseries and wards, corridors of hospitals for contagious diseases, school rooms, offices and public rooms where people congregate. The third type is used in air-conditioning systems, in food-processing rooms where exclusion of bacterial contamination is important and for purification of air or other gases used in food handling.

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PART IV

Essentials of Hydrotherapy and Mechanotherapy

CHAPTER XX

HYDROTHERAPY

General Considerations. Physical Principles. Physiological Principles. Hydrothermal Measures. Wet Compresses. Wet Packs. Ablutions. Baths. Special Forms of Baths. The Elliot Treatment Regulator. Hot-air Baths. The Paraffin Bath. Hydrokinetic Measures. Douches and Showers. The Whirlpool Bath. Therapeutic Pools and Tanks. Colonic Irrigation.

General Considerations.—The term hydrotherapy designates collectively the therapeutic procedures related to the external application of water and other forms of baths to the body. One cannot speak of water treatment without specifying what form of physical energy it conveys, just as one cannot speak of electrical treatment without stating what form of electricity is employed. In practically all forms of water applications used for treatment thermal effects play the leading rôle; in many of them the mechanical effects of immersion, of the pressure and of the flow of water exert, in addition, certain specific action. Hence the classification of water treatment under the two headings of *hydrothermal* and *hydrokinetic* measures. There occur also hydrochemical effects in addition to hydrothermal effects with some special forms of baths.

In the modern development of hydrotherapy an imposing array of apparatus was devised for the application of the various water treatment measures. In proportion as the complexity of the outfits increased their employment in general decreased, for instead of encouraging the use of simple hydriatic measures in the patient's home or in the physician's office, hydrotherapy became almost entirely a method of institutional use. It is a fact, however, that in trained hands, with no more expensive and complicated implements than a supply of hot and cold water, a bathtub, a few towels and sheets, a multiplicity of remedial effects can be accomplished.

Physical Principles.—The employment of water as a physical therapeutic agent depends principally on its property as a medium for the conveying of certain physical forces.

Water has a great capacity for absorbing heat, its specific heat being highest of all ordinary substances except hydrogen. It cools relatively slowly. It is, therefore, valuable as a medium for abstracting heat, for storing heat and for applying heat. Its utility as a thermal agent is further enhanced by the ease with which its temperature can be measured, regulated and controlled.

Water can readily be applied with varying and regulated pressure. A body immersed in water is buoyed up by a force equal to the weight of water it displaces. Ingenious use has been made of this principle in recent years for underwater exercising of muscles, too weak to work outside of the water.

TABLE 47.—TEMPERATURES OF WATER APPLICATIONS

Cold bath	40° to 65° F.	(4.4° to 18.3° C.)
Cool bath	65° to 75° F.	(18.3° to 23.8° C.)
Tepid bath	85° to 95° F.	(29.4° to 35.0° C.)
Warm bath	95° to 100° F.	(35.0° to 37.7° C.)
Hot bath	100° to 110° F.	(37.7° to 43.3° C.)

Physiological Principles.—The human skin may be regarded as a great sheath of imperfectly sheltered blood-vessels and nerve endings and the effect of hydriatic measures is essentially a reaction in the skin and in the organs reflexly connected. It has been shown by physiologists that there are special nerve endings, "receptors," for heat and cold in the skin. The more intense the stimulus, the larger surface of the skin it affects and the longer it lasts, the more intense will be the reaction caused by it. About 25 per cent of the blood of the body is contained in the capillary beds, many of which are in the superficial tissues, especially in the limbs. Heat and cold, manipulation through the skin can more profoundly influence the distribution of blood than any medicinal measure. There occurs also an exchange of ions in a bath between the water and the skin tissue, with some change in the structure of the skin itself.

The normal or average temperature of the human body under the armpit is 98.4° F.; the average temperature of the skin surface is much lower, about 92° F., due to constant cooling through the evaporation of the moisture on its surface. If water at a temperature different from that of the skin is applied to the body it either will conduct heat to the body or absorb heat from it. The difference in temperature acts as a "stimulus" or irritation of the nerve endings of the skin. By such stimulation one can influence the balance of the sympathetic system and also affect the endocrine system. Tepid water, at a temperature of 92° to 94° F. causes no external stimulation of the skin nerves and is principally used to exert a marked relaxing, nerve-resting effect upon the entire body. One can lie in such a bath for hours in perfect repose.

The greater the difference from the normal skin temperature, the more marked are the physiological effects of hot and cold water applications. Short applications of intense heat or cold are equally stimulating.

1. **Cold Applications.**—A short *cold* application exerts the most profound effect among all water procedures. Under its influence the skin becomes pale and usually takes on the appearance of goose-flesh, which is due to the constriction of the small blood-vessels and the contraction of the muscular and elastic tissues in and under the skin. If the application lasts only a short while, the constricted blood-vessels immediately dilate again, more blood flows through the parts than before and the skin becomes pink and feels warm. At the moment of application deep inhalation occurs with a momentary arrest of the respiratory movement—the familiar "gasping," which is followed by deep exhalation and the respiratory movements continue deeper, especially if the cold application is prolonged. The sum of these stimulative effects of a cold application on the circulation and other vital functions is known as a cold "reaction." Many of the hydrotherapeutic measures have as their object to bring about such an effective reaction. In persons of low vitality—poor circulation, scanty respiration,

run-down condition—cold applications do not bring about such a reaction and are, therefore, to be avoided. In normal persons a sensation of well-being and that of a general stimulation follows a good cold reaction.

Other physiological effects of a short cold application are the slowing of the pulse, an increase of the tone and work of the heart muscle, provided that it is not too weak to overcome the increased resistance in the peripheral circulation. The blood-pressure shows an initial rise and later a fall but it usually stays higher than before the application, due to the increased tone of the blood-vessels.

Cold applications of long duration cause primary contraction of blood-vessels, followed by their paralysis due to damage of the nervous system of the vessel wall. More about these effects will be said in the chapter on hypothermy.

2. **Hot Applications.**—A short intense *hot* application causes the same immediate vascular reaction as a cold one, the skin blanches, the tissues contract and goose-flesh appears. Plunging one leg or arm for a second in very hot water will demonstrate this. This primary effect, however, subsides quicker than after a cold application. A dilatation of the peripheral blood-vessels also follows but the resulting hyperemia is more widespread and is atonic in character in contrast to the reactive hyperemia induced by cold. The local and general physiological changes following the continued application of hot water within physiological toleration correspond with those described in Chapter XI. Too intense heating leads to tissue destruction and permanent damage, just as too intense cold application.

3. **Applications of Slowly Increasing Temperature.**—Applications of slowly increasing temperature through the medium of water cause a dilatation of blood-vessels and a gradual rise of the skin temperature. With an arm or leg bath of increasing temperature, the peripheral arteries become dilated and more blood is drawn into the extremity. In recent years it was found that by partial baths of increasing temperature, it is possible to influence the peripheral and general circulation more effectively than by the abrupt stimulus of intense hot or cold applications.

Mechanical force adds considerably to the stimulating effect of any hydriatic application. The force of the impact of the water and the amount of friction during and after treatment are important factors in determining the total effect of a hydrotherapeutic reaction.

An interesting table by Fox and Van Breemen[1] presents a scale extending from stimulation to sedation by external heat—chiefly hydrothermal.

TABLE 48.—A SCALE OF SEDATION AND STIMULATION BY EXTERNAL HEAT (FOX AND VAN BREEMEN)

Accelerating or stimulant—
- Hyperthermal mud (115° to 120° F.)
- High-pressure douches, hot or cold (with or without strong manipulation)
- Vapor baths (hot)
- Whirlpool baths
- Brine baths
- Diathermy
- Hot-air baths
- Half baths
- Radiation baths (light, heat, ultraviolet)
- Low-pressure douches } All at 93° to 98° F.
- Vapor baths }
- Pool baths (with or without sedative manipulations)

Retarding or sedative

Among the large variety of hydrotherapeutic measures principally those will be discussed which lend themselves for application in general practice or the use of which has become an essential part of modern physical therapy.

HYDROTHERMAL MEASURES

Wet Compresses.—In all compresses a folded linen cloth serves as a vehicle for the application of either hot or cold water. Compresses are slightly wrung out and held in position by a dry flannel bandage.

A *cold compress* causes contraction of the peripheral vessels and is for this reason a valuable measure for immediate relief in recent injuries, as well as in early stages of inflammation, for combating swelling, redness and pain. In order to maintain fairly even cooling, the compress should be renewed frequently, every one-half to one minute or kept cool by a coil with circulating cold water or an ice-bag.

Cold compresses to the forehead are useful in cerebral congestions of various origin. Applied to the nape of the neck they are sedative in nervous disorders, such as nervous palpitation and in nervous sexual excitement. A cold precordial compress is valuable in nervous irritation of the heart.

A *stimulating compress* is a cold compress covered over with several layers of dry flannel so that they completely overlap the wet linen underneath. With the compress left in position there is at first a vasoconstriction but as soon as a reactive vasodilatation sets in, the compress becomes warmed from the increased supply of blood; due to the insulating covering, it takes on the temperature of the blood, its water content evaporates and it becomes dry, within one to four hours.

The mild vascular skin reaction of the stimulating compress is a convenient treatment measure in many acute congestive conditions. A *throat* compress is useful in sore throat, laryngitis and tonsillitis. A *chest* compress serves in diseases of the respiratory system, bronchitis, pneumonia and in pulmonary tuberculosis. It should be followed by a local or general cold application or in patients with night sweats with an alcohol rub. The *abdominal* compress exerts a depleting and soothing effect in gall-bladder or liver congestion and in venous stasis of other abdominal organs. It is applied so as to cover the parts from the costal arch to the symphysis and may be applied overnight in ambulatory patients and several times during the day in bed cases. Many patients with abdominal complaints regularly sleep in this compress and feel greatly benefited.

Stimulating compresses should not be applied in patients with eczema and should be discontinued if there are signs of skin irritation. A compress in use should be boiled daily to prevent infection of the skin.

A *hot compress* is applied much in the same way as the cold compress with several layers of folded linen cloth dipped in hot water (105° to 115° F.) and covered with flannel or woolen cloth to maintain the heat. Kept on for one to two hours it will bring on an intense hyperemia and help to soften or disintegrate inflammatory congestion and also relieve pain and spasm.

Wet Packs.—Wet packs are among the most effective of hydriatic measures. According to the temperature of the water employed, we distinguish between cold wet packs for sedation and antipyretic effect and hot wet packs for elimination; according to the extent and size of the pack, we distinguish between full and three-quarter packs.

The *full wet pack* needs the following equipment (Council of Physical Therapy): Any ordinary bed and mattress; if packs are to be repeatedly renewed, two beds and double equipment must be provided. A stool, small table or straight chair should hold a pillow, rubber sheet or large piece of oilcloth, one or two sheets (72 by 99 or 80 by 90), three or four heavy woolen blankets (72 by 84 or 80 by 90), two small towels, a hot-water bottle or hot soapstone. The room temperature should be 68° to 72° F.

The pack is applied as follows: Prepare the bed by spreading a rubber sheet next to the mattress and spread two or three woolen blankets over the rubber sheet. Best results are obtained when the sheet is folded in such a way that it may be easily spread out under the patient while he is reclining on the bed; fold the sheet lengthwise and in plait-like folds of 6 or 8 inches wide; now fold crosswise forming a bundle 6 or 8 inches wide and approximately 30 inches long; this leaves the sheet in a convenient form to be immersed and wrung out; the sheet is dipped in cold water 60° to 70° F.

"Prepare the patient; patient should be in the nude; turn the patient on his side and over to one side of the bed; lay the sheet in the middle of the bed open crosswise but still folded lengthwise; it will look like a white strip dividing the middle of the bed; unfold half of the sheet; spread it over the vacant portion of the bed on top of the blanket; place top edge of blanket 1 inch below the patient's shoulders; roll the patient on the wet open half and spread the other half; patient will shudder at first contact with the cold wet sheet; discomfort should pass quickly; tuck the sheet snugly around the patient; have patient raise arms above head; fold one-half of wet sheet closely over the patient, high under the arms; tuck edges smoothly under body and legs; press a fold down between the legs and feet; be sure the sheet clings snugly to the body everywhere; put patient's arms down to sides; wrap the remaining half of the wet sheet around the patient—upper edge closely surrounding neck; fold lower end under the heels; sheet should be snug but not binding; too tight wrapping makes the patient both uncomfortable and apprehensive; be sure to guard against cold feet and any prolonged chilling; work fast.

"Now wrap the blanket smoothly around the neck and over the chest; tuck corner under the shoulder, and edge under body; patient should be getting thoroughly warm now and becoming relaxed; if feet will not warm up, use hot-water bottle; a towel might be tucked around the patient's neck for comfort.

The patient should not be left alone in a pack at first, as, if weak, he may suffer from shock and require a hot drink or aromatic spirits of ammonia or even have to be taken out, though this is a rare occurrence. The pack may last from fifteen minutes up to one hour. When taken out, a rub should be given with a coarse towel or alcohol or in the form of a warm sponge bath, according to individual circumstances, in order to restore the tone of the relaxed peripheral vessels. Be sure the skin is thoroughly dry before putting the patient to rest in a warm bed.

A *three-quarter* pack may be applied in nervous patients who cannot tolerate being fully wrapped up. In this technique, the wet sheet and blanket are only applied up to the arm-pits, the arms being left free and covered separately with a blanket. The result is almost identical with that of a full pack.

The *physiological effects* of the full wet pack are as follows: The contact of the cold wet sheet with the skin causes reactive peripheral hyperemia. The heat released from the dilated blood-vessels accumulates between the skin and the pack, forming a layer of warm air. A sedative or even hypnotic effect is produced by the action of warm vapor on sensory nerve endings, by depletion of cerebral vessels resulting from repletion of peripheral vessels, by the absolute immobility enforced by the snugly fitting pack and by the entire absence of mechanical stimulation. The pulse-rate and respiration are slowed after primary stimulation. Repeated wet packs are antipyretic in effect.

The cold wet pack is one of our most effective sedatives as many patients fall asleep within a short time. In psychoses, psychoneuroses and some forms of insomnia resistant to medication it is a measure of great value, but it is contraindicated in debility, in marked degree of circulatory disturbance or in cardiac weakness.

Ablutions.—Pouring water over the entire body or part of it serves as a mild form of thermal stimulation for getting the patient accustomed to cold water and also for judging his vascular reaction. For a *full ablution* the patient may sit in an empty bathtub or lie on a rubber cot. Water at a temperature from 60° to 70° F. is poured from a pitcher over the back and the chest. This deepens respiration and stimulates and refreshes the nervous system but as it also raises blood-pressure it is contraindicated where this is too high. The degree of stimulation is in proportion to the temperature of the water employed and the height from which it is allowed to descend upon the patient. This procedure should be a very short one to attain the desired effect.

The *partial ablution* or *towel bath* is a milder measure for bringing about a local vascular reaction without increasing the blood-pressure. It is administered to a patient lying in bed, covered only with a sheet and blanket. Towels are placed in a bucket containing water at 65° F. and after wringing, spread in succession over the arms, legs, chest and back. While each towel is in position, the attendant rubs it until it feels warm. As the wet towel is removed from one area, the skin is quickly dried and the part is covered with the blanket and the next area is treated with another towel from the bucket. The total duration of treatment should not be more than five minutes, following which the patient should remain in bed for some time, sleeping if possible.

The towel bath can be employed with benefit in febrile cases and in elderly people and it can be safely repeated a number of times. It exerts a mild stimulating effect.

Hot and Cold Baths.—Baths may be classified according to their extent as full or partial baths and according to their temperature as cold, tepid and hot baths. The effect on the body varies to a certain extent according to individual susceptibility and gradual accustoming to certain procedures. The immediate sensation upon entering any bath will also depend on the skin temperature at that time; if the patient's skin is warm and perspiring, a tepid bath may feel cool, while with a cold skin, the same bath temperature may feel warm.

Short Cold Baths.—A short cold bath or plunge is given in a tub for a few seconds to two minutes at a temperature ranging between 80° and 65° F. If necessary the skin should be previously warmed by some other procedure and then the face and neck bathed with cold water. While the body is immersed in water it should be vigorously rubbed or the bather should exercise. As soon as the patient has rubbed himself dry with a turkish towel he should exercise moderately or receive a general massage.

As a water treatment measure a full cold bath requires the strongest reactive response from the patient. It is generally contraindicated in high blood-pressure, weak heart or tendency to hemorrhage and when employed at any time should be always combined with brisk friction in order to assist the reactive power of the patient.

A cold plunge bath in the morning is an excellent tonic and hardening measure for healthy people and is followed by a definite rousing of the vital energy of the body, a glowing pink skin and alert zest for the day. In chronic conditions with diminished functional activity—atonic constipation, obesity, mental lassitude—it should be carried on systematically.

Continuous Tepid Baths.—A bath administered at a temperature from 94° to 98° F. for continuous periods is one of the most effective of sedative measures and is widely employed in mental hospitals for quieting disturbed patients.

Hot Baths.—Full tub baths at a temperature of 100° to 108° F. are known as hot baths.

The temperature of the room in which a hot bath is given should be between 70° and 80° F. and warm towels and sheets should be in readiness. The temperature at the start should be minimum and be quickly raised after the patient has been immersed to the chin. The bath is continued for ten to twenty minutes, in which time there occurs a rise in the blood-pressure and body temperature, as well as in the frequency of the pulse and, as a rule, profuse perspiration sets in. The mouth temperature usually rises to 101° F. in thirty minutes. Upon termination of the bath, the patient may receive an alcohol rub or a quick cold water application or he may be rapidly dried and wrapped up in hot blankets, especially if further perspiration is desired.

The hot bath brings about an increase of metabolism and elimination. In chronic arthritis and rheumatoid conditions hot baths at a temperature from 96° to 102° F., employed from five minutes to one-half hour, two or three times a week are a most useful measure for home treatment.

Hip and Sitz Baths.—These are local baths and may be employed in the form of hot, tepid or cold baths. Any tub not higher than 1 foot may be used, though for institutional use special tubs are built, supporting the patient's back and arm. There should be enough water to reach to the umbilicus of the patient when he is seated in the tub and he should be protected from chilling by suitable covering, especially over the legs and feet.

The sitz bath acts on the abdominal and pelvic organs, its action depending on the temperature and its duration. A *short cold* sitz bath, at a temperature of 65° F. given for a few minutes acts as a strong stimulus on the abdominal blood-vessels and intestinal muscles. It must be accompanied by vigorous friction of the abdomen. A *long cold* sitz bath at 65° F., lasting from ten to fifteen minutes causes a more prolonged contraction of muscles and is useful in combating inflammations and hemorrhage; it is contraindicated in spasms and abdominal colic. A *hot* sitz bath, at a temperature from 110° to 115° F., lasting for fifteen minutes, causes after a short initial contraction a relaxation of all parts and is, therefore, helpful in combating spastic conditions of the abdomen and pelvic organs but it is contraindicated when there is already a good deal of congestion.

Contrast baths consist of alternate immersion of a part in a pail of hot water—105° to 110° F.—for three minutes and cold water—60° to 70° F.—for one minute, repeating this cycle several times. Constant temperature is maintained by frequent addition of hot or cold water. This performance causes an intense vascular reaction in the circulation and may cause quite a strain in peripheral vascular disease on account of the extreme vasoconstriction. Hence contrast baths should not be used in advanced circulatory disturbances, but may be usefully applied in sluggish circulation following wounds and scars, for the toughening of amputation stumps and their preparation for massage; also in chilblains.

SPECIAL FORMS OF BATHS

The *carbon dioxide bath,* also known as the Nauheim bath, consists of the application of either spring water saturated with natural carbon dioxide gas or is produced by various methods of artificial carbonization. The active principles are the temperature of the water and the stimulus exerted by the carbon dioxide bubbles of minute size. Such a bath affects the blood-vessels and the heart action causing a dilatation of the peripheral vessels, increasing pulse-pressure, the cardiac output and the blood-pressure. Carbon dioxide baths cannot be given or should not be given in a routine manner but by experienced medical men and highly skilled technical personnel.

Medicated baths containing aromatic, resinous and other substances have received attention from time to time but offer only a very limited scope of usefulness. *Aromatic baths* are prepared by the addition of pine needle extract, extracts of aromatic herbs; they add to the pleasantness of a warm bath, but not to its actual effect. *Resinous baths* containing irritating vegetable substances in suitable concentration may exert very marked irritation of the skin as shown by a burning sensation and subsequent redness. Extravagant claims made as to supposed special benefits in rheumatic conditions have not been corroborated by any large scale clinical experience.

The *galvanic bath* consists in the application of a galvanic or other forms of low-tension current through the medium of water to the body surface. (Chapter VIII.)

The Elliot Treatment Regulator.—In the Elliot treatment conductive heating is applied to body cavities and nearby organs from a thermostatically controlled water bath; an electrically driven pump circulates the heated water through slightly distensible, gum rubber applicators. The applicators are interchangeable so that the size and shape can be varied according to the lumen of the part to be treated: the vagina, rectum, nose and eye. The Elliot apparatus holds 2 quarts of water, which can be applied at a temperature beginning at 115° to a maximum of 130° and a pressure of 1 to 3 pounds. Treatment may start at fifteen minutes and gradually increase up to one hour.

The effects of this treatment are those of all other forms of local heating, namely improvement of circulation, relief of pain and congestion, resorption of exudates. The special advantages claimed for the Elliot technique is the even and generally diffused heating and the regulable amount of heating and pressure. The clinical indications are chiefly acute, subacute and chronic inflammatory conditions in the pelvis, rectum and bladder. The possible dangers are the rare rupture of the rubber applicators and subsequent scalding; more frequent are various degrees of burns following excessive heating. Contraindications to pelvic heating are profuse menstruation, uterine hemorrhage, tumors, much scar formation and severe secondary anemia.

Hot-air Baths.—Hot-air and steam baths make use of extreme temperatures and are usually administered in cabinets which enclose the entire body with the exception of the head. The advent of electric light cabinets has made most of the older forms of hot-air and steam baths obsolete; on the other hand, the modern interest in fever therapy has led to the development of several forms of highly efficient cabinets for artificial fever production as described in Chapter XIII.

Local application of hot air for treatment of cavities, especially the pelvis, has been made possible through an arrangement similar to the Elliot treatment regulator; instead of hot water, hot air is kept circulating in the rubber applicator from a heating unit. (See Chapter on gynecological conditions.)

The Paraffin Bath.—The paraffin bath is a simple and efficient method of applying a fairly high degree of surface heating. It consists of immersion of the extremities into melted paraffin or the application of paraffin with a paint brush to the surface of the body. Ordinary commercial paraffin, with the addition of a little paraffin oil, melts at around 130° F. Due to the low heat conduction of paraffin, the average skin tolerates such temperature quite well. On immersion of an extremity the melted paraffin congeals around it, as body temperature is below its melting point. The semisolid paraffin wax forms a coating which transmits to the skin the heat of the melted part. Under this coating the skin sweats, and the vapor of this and the entangled air acts as an insulator and prevents burning of the skin. The result is great local flushing and sweating and a raised temperature, not only of the extremity but of the whole body, if a large enough surface is immersed. Careful temperature tests have shown the skin temperature in a paraffin bath after the formation of the protective "glove" is around 116° F. and patients feel comfortable. It renders the skin soft and pliable, thus in good condition also for subsequent massage and exercise.

For applying the paraffin bath a simple home-made outfit consisting of a $1\frac{3}{4}$ gallon double boiler, an electric or gas stove and 8 pounds of paraffin may suffice. The lower part of the boiler is filled with hot water and the upper part contains the paraffin. The boiler is heated until almost all paraffin is melted. The heating of the boiler is now discontinued, and the bath is ready for use. As long as an unmelted piece of paraffin remains, the temperature of the bath is safe for use.

A more efficient form of paraffin bath is an electrically heated metal bath, in which the melting point of the paraffin can be set at a somewhat higher point (136° F.) by thermostat control and subsequently maintained

FIG. 248.—Paraffin bath, with thermostatic control.

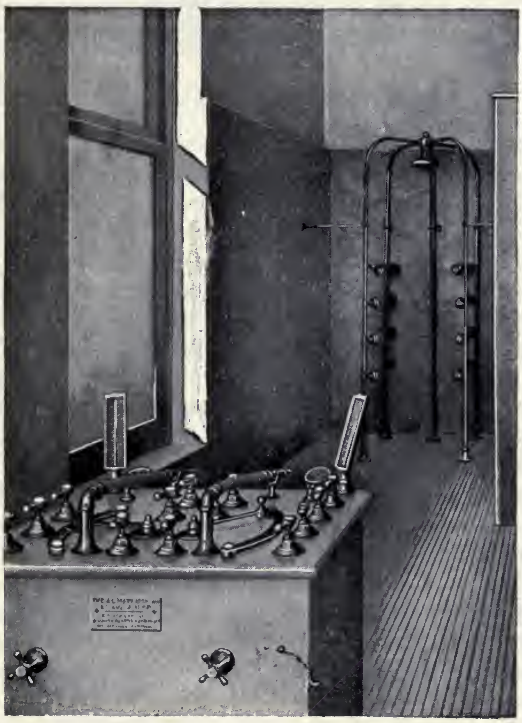

FIG. 249.—Portion of douche room showing control table and combination douche (background) where patient stands during treatment.

at an operating temperature of about 10° lower. Slats of bakelite or wood fastened to the bottom of the metal tank, safeguard against the touching of the heated metal by the immersed part of the patient's extremity. The use of a suitable thermometer is an additional safeguard.

In applying a paraffin bath, the part to be treated is first washed and dried. The patient is instructed to dip in the hand or foot quickly and lift it out so that only a thin coat of paraffin congeals on the skin. Repeating this procedure from six to twelve times gradually a paraffin glove of sufficient thickness is formed and the extremity then can be kept safely immersed in the bath. After ten minutes to one-half hour, the extremity is lifted out, the glove is taken off by gentle traction and the part is ready for further procedure.

In treating body surfaces not suitable for immersion, a warmed paint brush is dipped in the bath and with quick strokes several coats of liquid paraffin are applied. The congealed coating is kept on up to one-half hour. The peeled off glove or coating is in either case placed back in the bath, where it melts and is thus used over again. Bacteriological tests have shown that, after a while, the paraffin in the tank becomes sterile again and with ordinary cleansing precautions, these tanks are quite sanitary; they can be also fully sterilized with thermostatic control.

The paraffin bath is useful in the after-treatment of traumatic conditions involving the extremities, such as swelling and stiffness following fractures, sprains, contusions, lacerations and infections. It is also quite effective in chronic arthritis of the hands. In disturbed skin sensation following nerve injuries and in recent thin scars, the bath can be applied only with great care. It should not be used at all in case of skin infections and open wounds.

HYDROKINETIC MEASURES

In the employment of hydrokinetic measures combined use is made of the temperature and pressure of water or its lifting power. Among these measures belong douches and showers, the whirlpool bath, therapeutic pools and tanks and colonic irrigation.

Douches and Showers.—Showers consist of streams of water projected under pressure in a fixed direction, while with douches the direction of the stream can be moved over any part of the body. Alternately hot and cold douche application is also known as a Scotch douche. For the administration of all forms of douches at various pressures and temperatures a hydrotherapeutic control table serves, which is part of the more elaborate institutional equipment.

The Whirlpool Bath.—The whirlpool bath is a hydrokinetic measure, in which water at a temperature between 110° and 115° F. is kept in constant agitation in a vessel which holds an arm or a leg. As a result of the combined action of heat and the gentle mechanical and softening effect of the whirling water, the immersed extremity shows a marked response. After fifteen to forty-five minutes of such "hydromassage" the skin becomes pink and feels warm, inflammatory induration is softened, pain and spasm relieved, the repair of wounds stimulated, the removal of necrosed tissue and pus is speeded up.

There are several types of apparatus. A simple home outfit can be made from a washboiler with suitable hot water and air inlet and water ejector working under ordinary water pressure. Another portable type consists of an electric washing machine, capable of ejecting 300 cubic feet of water a minute, attached to a tank on wheels; the tank can be raised or lowered for either arm or leg treatments. The most efficient types are stationary baths connected with a mixing chamber, a thermostatic valve and a pressure gauge; by these means the temperature and pressure of the water can be accurately regulated and maintained during treatment. Mixing the inflowing water with air, by means of a so-called aërator, a large number of air bubbles add to the mechanical stimulation.

Fig. 250.—Portable hydromassage apparatus. (Courtesy of Ille Electric Corporation.)

The whirlpool bath is a most valuable treatment measure in a large number of traumatic and chronic inflammatory conditions. It is excellent for early treatment of stiffness, pain and sluggish skin circulation following fractures and constitutes the best treatment which can be given as soon as a fractured limb can be taken out from its immobilization. In painful scars, adhesions, peripheral nerve injuries and some forms of neuritis, joint stiffness and suitable cases of arthritis, tenosynovitis, indolent and chronic suppurating wounds, painful stumps, weak and painful feet it is also employed with benefit.

In administering the whirlpool bath the part must be gently placed in water; the temperature should be slightly lower at first and then gradually raised. The arm or leg should be well supported. In case of nerve injuries with impaired sensation, care must be exercised to prevent scalding. The bath also serves as an excellent preparation for subsequent massage or electrical treatment by making the extremity more supple and less sensitive.

Therapeutic Pools and Tanks.—Underwater exercises (hydrogymnastics) for infantile paralysis have aroused country wide interest in recent years and their scope has gradually extended to include many other conditions. Therapeutic pool treatment takes advantage of two facts: (1) the buoyancy of the water reduces the weight of the body and largely eliminates gravity; thus muscles too weak to perform outside of water can be actively exercised; (2) the heat of the water relaxes spastic muscles and improves circulation. In outdoor pools fresh air and sunshine add to the beneficial general effect; in salt water pools, there is specific effect on wound healing and added buoyancy.

Fig. 251.—Large Hubbard tank. (Currence.)

Fig. 252.—Hydromassage tank with turbine ejectors, also showing overhead body stretcher for conveying patient into tank. (Courtesy of Ille Electric Corporation.)

Much money has been wasted on the building of elaborate, large pools requiring an expensive upkeep. Only in large, specialized orthopedic institutions is there justification for such outlay.

Large and small tanks of the "Hubbard" type enable full extension of all extremities in a T-shaped vessel. They serve for individual treatment in institutions and also in homes. In the original Hubbard tank children of all sizes can be treated. It is inexpensive being made of galvanized iron.

For home treatment, in emergency, even a large bath-tub can be employed. A larger tank (Fig. 252) serves for the treatment of adults.

The principal factor in administering underwater exercises is the skilled technician. Special training is required to become fully familiar with the action of all muscles and the means of exercising the muscles lacking function, according to the directions of the attending physician. For further details of treatment technique see Chapter on exercise.

Underwater exercises are now employed not only in the after-treatment of infantile and spastic paralysis, but also in many traumatic and orthopedic conditions and in suitable cases of chronic arthritis, especially of the osteo-arthritic type.

Colonic Irrigation.—Colonic irrigation forms part of the routine work of most hospital physical therapy departments and of physical therapy specialists' offices, because of the special facilities and skill needed for its administration. The principle of measured suction and pressure embodied in modern colonic treatment apparatus has made these particularly efficient and safe. The indications for colonic irrigation are: impactions and threatened obstructions of the large bowel; chronic or acute toxemia, from absorption of putrefactive products; preparation for surgery to prevent postoperative gas pains, from decomposition of retained material; preparation for fever therapy, where absorption of toxins from retained feces adds to the hazard; postoperative clearing on the fourth or fifth day after surgery, to remove hardened feces and gas; amœbiasis, trichomonas and other parasitic infections; diagnostic aid in all disturbances of the alimentary tract.

REFERENCE

Fox, R. F., and Breemen, J.: Chronic Rheumatism, Causation and Treatment, London, J. and A. Churchill Ltd., 1934, p. 253.

CHAPTER XXI

HYPOTHERMY

General Considerations. Methods of Hypothermy. Physical and Physiological Effects. Therapeutic Considerations. Local Hypothermy. General Hypothermy. Cold Injuries. Chilblains. Immersion Foot. Frostbite.

General Considerations.—The term cold denotes subjectively the sensation which is brought about by contact with a substance whose temperature is lower than the normal; objectively a condition of material bodies which gives rise to that sensation. When a warm body is brought into contact with a cold body the former is cooled while the latter is warmed. Thus the exchange of heat between two bodies which are at a different temperature results in a gain of heat to the colder body and a net loss of heat from the hotter body until they finally arrive at the same temperature. During the progressive development of modern physics it was a debated question whether cold in the objective sense was to be regarded as a positive quality or merely the absence of heat. The general acceptance of the dynamical theory settled this question, for under its meaning cold is to be regarded as a negative condition, depending on decrease in the amount of the molecularvibration that constitutes heat.

The elementary observations on the therapeutic effect of different degrees of thermal application can be traced to Hippocrates, the master medical mind of ancient Greece, who in 450 B.C. recorded the first reliable observations on the effect of hot and cold water upon the body. He stated: (1) that cold water warms, (2) whilst warm water cools the body, (3) that warm shower baths induce sleep, (4) that cold water stimulates, and (5) he recommended cold water to assuage fever and pain.

Cooling or chilling by cold water applications at various temperatures in order to produce general or local stimulation, or mild sedation, has for a long time formed the mainstay of modern hydrotherapy. These procedures, as described in the preceding pages, are generally of short duration and as a rule are accompanied by changes of skin temperatures only. In recent years extensive clinical and laboratory work has been carried on with applications of cold for prolonged periods with the object of lowering temperature and metabolism in deeper parts or the entire body, also to bring about destruction of tissue or local anesthesia in certain cases. Dermatologists were first to use liquid carbon dioxide and carbon dioxide snow to destroy superficial growths by freezing. This method was named cryotherapy, or chrymotherapy (Kryos: cold). Fay and Smith[23] were the first in the United States to report on clinical research on the effects of local and general "refrigeration" upon malignancies, while Allen and Crossman[1] first demonstrated the value of the refrigeration method for amputations. Much additional clinical work was done lately with use of sustained cold applications in peripheral vascular disease and in military and industrial surgery.

The term refrigeration is apt to cause misunderstanding. Water freezes at 32° F. (0° C.), blood and tissues at a slightly lower degree. With the original methods of refrigeration, surrounding the body or a limb with ice-water and cracked ice results in lowering the temperature to 0.5° to 5° above freezing, hence refrigeration brings about chilling but not freezing of the tissues. With the latest mechanical devices for cold treatment the degrees of lowering the temperature can be exactly regulated, hence the general term of hypothermy or hypothermia appears more appropriate and by general consensus is being used to denote the sustained application of cold for lowering body temperature. This is in keeping with the accepted use of the term hyperthermy for raising body temperature for therapeutic purposes. Most of the techniques of hypothermy make use of water or ice and hence the presentation of this subject as part of the section on hydrotherapy seems appropriate.

Fig. 253.—Wooden refrigeration box with galvanized tin lining; outlet tubes for drainage at distal end; tourniquet around limb to be amputated is not depicted; box is to be filled with small pieces of ice and lid is fastened in place. (Dr. J. D. Gordon.)

Methods of Hypothermy.—The *ice-bag* is a time-honored device for the application of cold to a small flat area, such as the trunk or the abdomen; it is difficult to adjust and to hold over a rounded surface as the head or the neck. In multiple numbers thin ice-bags can be used over larger areas for general body cooling but they must be kept constantly refilled to maintain a fairly even degree of cold.

Ice-water is quite simple and effective for chilling the distal parts of an extremity.

Finely cracked ice offers the advantage of moulding the cold application to the part and is quite easy to apply. It needs to be constantly replaced as it melts and the water from the melting must be led away so as to keep the patient fairly dry. A simple ice filled refrigeration box for amputation has been described by Gordon.[11] (Fig. 253.)

Mechanical apparatus for hypothermy is more complicated and more expensive but when efficient it enables the maintenance of temperature at any desired level and enables local as well as general body treatment.

Fig. 254.—General hypothermy to patient in hospital bed, using underpad and overblanket connected to refrigeration apparatus. Also note hood for head treatment. (Courtesy of Therm-O-Rite Products Co.)

An apparatus constructed by Brenner is a cabinet unit containing a brine tank, electric pump, pressure and temperature control; the refrigerating device cools a fluid (35 per cent alcohol) and pumps it through suitable tubing. It can produce thermostatically controlled temperatures from 20° to 130° F. without the use of ice. When used for general hypothermy, the patient is entirely enclosed within an underpad and over-blanket which, when zipped up the sides and around the shoulders, resembles a sleeping bag. It can be used in the regular hospital room and does not require the 50° F. room temperature necessary when ice is applied directly to the body. (Fig. 254.)

Single extremities can be cooled by envelopment in flexible applicators, made of waterproof material and containing rubber tubing channels through which the cooling fluid circulates rapidly. For treatment of local areas or cavities metal applicators serve as illustrated in Figure 256. They are made of copper and chromium or silver plated. There is also available a hood for head treatment which entirely encloses the head with the exception of the face.

A similar type of apparatus for general body treatment has also been described by Bigelow and Lanyon.[5] For treatment of an extremity, Eve[9] has suggested the use of cold air by a simple gravity method. His device consists of a metal cylinder containing ice and salt, enclosed in a second cylinder; heavy cold air is formed in the space between the cylinders and flows through a hose to a cradle containing the limb and well insulated by blankets. Green[12] described an apparatus for extremity treatment making use of carbon dioxide. It consists of a cabinet with an upper and lower compartment. In the upper is a metal tray in which solid carbon dioxide

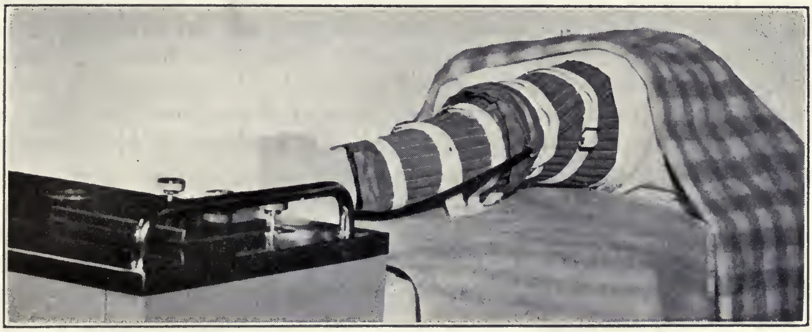

FIG. 255.—Local hypothermy to upper arm surrounded by waterproof applicator with rubber tubing. (Courtesy of Therm-O-Rite Products Co.)

is placed. The lower compartment opens in two sections and has two padded apertures for the hands or feet. It contains a thermometer which registers on a dial at the back of the cabinet. Air circulates through two flues between the compartments. These flues are controlled by knobs at the back, by manipulation of which the desired temperature can be maintained. The patient's feet or hands padded with cotton wool or bandages,

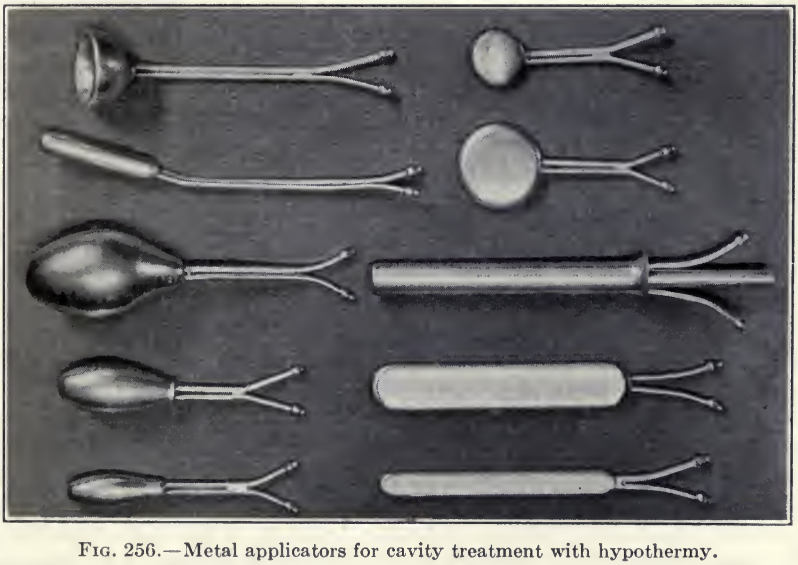

FIG. 256.—Metal applicators for cavity treatment with hypothermy.

are placed in the lower cabinet, then two blocks of solid carbon dioxide refrigerant are placed in the upper tray. The air flues are opened until the desired temperature is reached. The cabinet uses 8 to 10 pounds of refrigerant in twenty-four hours.

Various arrangements have been described in recent years for strictly local applications of cold. Hall[13] uses a regular refrigeration apparatus for quick freezing with applicators especially designed for gynecological therapy; it is equipped with a defrosting device which simplifies the withdrawal of the applicators from frozen tissue. Koskoff *et al.*[15] have described a method for freezing areas of the brain with liquid nitrogen as an adjunct in brain surgery for removal of vascular tumors and for obtaining biopsy specimens. Poppe[20] reported the use of a cold air blast from a current of compressed air blown through a coil of metal tubing packed in carbon dioxide ice, for treatment of precancerous skin lesions and hemangiomas. There are many modifications available for applying solidified carbon dioxide for skin conditions.

Physical and Physiological Effects.—The primary physical effect of prolonged cold applied locally to the tissues (local hypothermy) is a drop in temperature of the tissues exposed. This cooling effect is quite penetrating; it has been shown that with ice-bags applied to the abdominal wall a temperature drop of 7.5° to 15.6° F. is effected in thirty minutes in the intraperitoneal areas below, and that with ice-bags applied to the calf of the leg for one and a half to two hours, a drop of 15° to 26° F. is caused in the muscle 2 inches beneath the surface. Cold water circulated through the rectum for a prolonged period through a hollow metal applicator resulted in a fall of the urethral temperature as much as 23.8° F.; and with a similar arrangement in the vagina the urethral temperature dropped 8° F. in fifty minutes. Cold applied to the outer side of the cheek by a similar technique resulted in an average drop of 9.5° F. on the inner surface of the cheek in 30 minutes (Bierman and Friedlander.[1])

The physiological effects of lowered tissue temperatures are predominantly vasomotor: the vessels of the skin contract, blood flow is reduced and heat loss from the skin is diminished. The vasomotor constriction comprises three phases (Lewis[18]): a direct and persistent response of the superficial vessels by local contraction; a transient general vasoconstriction due to reflex action and finally a persistent general vasoconstriction due to cooling of the circulating blood by the returning cold venous blood.

The subsequent physiological effects of the local cold reaction are the reduction of the local blood volume, of cellular metabolism and oxygen needs of the tissue cells in muscles, also an anesthesia of the parts affected. After a prolonged exposure of a body area to cold the temperature may penetrate sufficiently to modify the activity of muscles causing them to be capable of slow movements only.

Pathological and destructive effects by cold are governed by the factors of duration and degree, although cold does not destroy tissue chemically in such a rapid and obvious manner as heat. The injurious effects of cold cause an inhibition or suspension of vital activities and this process may or may not be reversible. Immersion of a finger in ice-cold water for ten minutes produces severe pain and subsequent tenderness which may last for hours, but finally subsides totally. Cooling of the arm with an ice cube produces local redness which is the result of the release of a vasodilator substance in the skin as result of cellular damage. The first pathological effect of prolonged cooling is a definite swelling of the cooled part. As an example of edema Lewis states that hands immersed in water at 41° F. undergo in three hours a 15 per cent increase of volume.

The temperature of 43° F. is critical in relationship to the effects of cold upon the tissues according to Lake.[16] Sustained cold below this point produces actual damage and frostbite; above this point it causes vasomotor paralysis with its secondary effects.

General hypothermy or prolonged cold application to the entire body also produces a reduction in the chemical and physical processes or metabolism: the heart rate becomes slowed, staying over 50 beats per minute; the circulation of the blood is prolonged; the blood-pressure and peripheral pulse may disappear entirely for hours at a time and the peripheral veins collapse entirely; the respiratory rate drops to 12 to 14 per minute. No impairment of renal function is apparent. If fluids are given, they are excreted with very little loss through respiration or the skin. Urinalysis has been regularly negative. Postmortem examination has not revealed any acute or other changes possibly attributable to refrigeration. Lowering of body temperature to 88° F. and less has been successfully maintained for several days. Simpson and Herring[21] and Troedsson[26] have shown that in the cat, rabbit and even monkey a condition simulating hibernation can be induced by narcosis and a body temperature of 56° to 60° F. attained and maintained for hours. In applying general hypothermy to humans, narcosis must be administered—usually by the intravenous method—while the body temperature is being lowered. As the temperature passes between 93° and 92° F., a period of reflex shivering occurs on the lowering of temperature, and occurs also later when it is being allowed to rise again. The patient's mind usually remains a complete blank from the onset of the induction period.

Therapeutic Considerations.—The practical value of hypothermy has been demonstrated in four fields according to Fay:[10] (1) as a local analgesic and anesthetic, (2) as a bacteriostatic agent in combating infection, (3) as a sedative and alterative in certain psychopathic states, (4) as an agent of retardation of cell growth in certain malignant tumors.

Local Hypothermy.—The numbing effect of cold is generally well known. The use of an ice-bag and cold packs over the abdomen and the chest as an aid for painful visceral and thoracic conditions has been empirically established for a long time. The rationale of this procedure has been pointed out by Fay[10] on an anatomical and physiological basis. In localized and referred visceral pain cold produces reflex vasoconstriction and relieves congestion and stretch on vascular pain fibres, but to be effective on such pain it must be applied over the entire distribution of the involved spinal segment and root and the physician must be familiar with the normal skin pattern. Severe headache connected with real pain or tenderness about the head may be relieved by the use of cold in a head applicator constructed like a helmet. Fay states that in minor trigeminal neuralgia, consisting of painful involvement of the branches of the fifth nerve with demonstrable impairment of sensation the use of cold is beneficial, while cases of true "tic douloureux" or major trigeminal neuralgia are made worse by it.

Local hypothermy has been successfully employed as a preoperative anesthetic in gangrenous extremities. With the extremity placed in ice or ice-water in a simple container, complete anesthesia can be produced in the entire extremity within a few hours; after the operation, the further application of ice-bags to the stump not only controls the after-pain but also results in the control of edema, promotion of drainage, inhibition of infection and avoidance of shock. The rationale and technique of this procedure has been developed by Allen[1] and Crossman and its effectiveness has been corroborated by a number of surgeons. Allen and Crossman state that refrigeration anesthesia has reduced all complications, except pneumonia, frequent in such operations. Wound healing is improved, and the number of patients requiring reamputation is greatly reduced. They have practically banished electric cradles and other appliances for nonoperative treatment of diabetic or arteriosclerotic gangrene. Present knowledge of temperature adjustment in these cases is inadequate, however. There is no guide or standard except the patient's comfort; any temperature that causes severe or persistent pain is wrong.

Because of these effects and its ability to control hemorrhage, infection, pain and progressive shock, hypothermic anesthesia has also been recommended in compound fractures, severe burns, and crushing injuries of soft tissues.

In peripheral vascular disease local hypothermy is being advocated on the ground that in advanced cases heat may be contraindicated, as the metabolic requirements of the tissues are not met by the diminished blood flow. On the other hand, reduction of the temperature reduces cellular metabolism, makes the blood supply adequate and prevents gangrene. It has been shown that limbs can survive prolonged local cooling without danger in acute circulatory accidents with thrombosis and embolism and there is less danger of tissue necrosis and gangrene. For these reasons in peripheral vascular disease, as well as in "immersion feet" and frostbite, the systematic use of cold has been employed with marked relief of pain, subsidence of edema and a minimal amount of subsequent tisssue damage.

Large scale clinical experience in all phases of trauma associated with war and industrial accidents will undoubtedly further clarify the indications for the employment of cold treatments.

General hypothermy was originally introduced for treatment of advanced cancer cases, but no specific results were obtained except a marked diminution of hitherto uncontrollable pain. At present good results are claimed for general hypothermy in the mental condition of young schizophrenic patients who have been ill less than three years. In extensive burns general treatment in air-cooled rooms has been advocated in addition to local treatment by ice-bags on the ground that general vasoconstriction and decrease of body temperature serves to conserve the body energy and also promotes local recovery.

The indications and techniques of hypothermy are at present still in a stage of evolution and some of the experimental findings still await the test of extensive clinical corroboration.

COLD INJURIES

Cold injuries have received much study in recent years all over the world; their great prevalence has been due to the global warfare carried on in trenches, on the high seas, in the cold of air and in arctic regions. The mechanism of injuries due to cold is still a disputed and unsettled subject, partly because of actual differences in the causes and results. The effects of different degrees and durations of cold, of wet and dry cold, and of moisture with or without cold, besides complications by pressure, circulatory stasis and other factors, will require much study for clear elucidation.

Clinically and pathologically, tissue necrosis does not result immediately from the effect of cold but appears as a secondary complication. While necrosis may result from immediate action of cold, in practice this is seldom observed at ground temperature. Due to poor heat conductivity of human tissues, the effect of cold is in direct proportion to length of exposure. Time, therefore, plays a decisive rôle in chilling; brief action of cold, as employed in local anesthesia, is tolerated without ill effect. The course of necrosis is determined primarily by interference with or eventual complete stoppage in blood circulation.

Freezing has some points in common with burns, in that each can produce both local necrosis and systemic shock; but in general the injuries from cold have more tendency to chronicity, prolonged subnormal tissue vitality, persistent nerve disturbances (pain, hyperesthesia, or partial or complete anesthesia), and subacute or chronic vasomotor or circulatory abnormalities, with white, cyanotic, mottled or red colors at different stages.

Until a classification based on extensive modern research is adopted, it is best to follow the heretofore generally accepted scheme of classification: (1) lesions without destruction of tissue, circumscribed cold-induced lesions of the skin, as first-degree frostbite, erythema and chilblain; (2) lesions with destruction of tissue, consisting of (*a*) second-degree frostbite, erythema with blister formation and superficial ulceration, and (*b*) third-degree frostbite, *i. e.*, frost gangrene; (3) generalized conditions with involvement of the skin, *i. e.*, cold-induced diseases, death from freezing (Bering[3]).

Immersion foot and immersion hand are special types of cold injuries, caused by exposure to cold insufficient to cause frostbite. They occur chiefly in survivors of shipwrecks and resemble the trench foot of World War I.

Physical treatment methods play an important rôle in all schemes of treatment but in accordance with a gradual change in the conception of the pathology of cold injuries, the opinion as to the best method of treatment, especially as to the rôle of temperature, has been considerably changed in recent years.

Chilblains.—Chilblains, a first degree frost injury, caused by repeated exposure to mild degrees of cold, consist of an inflammatory reaction in the affected parts—toes, feet or fingers, which assume a violet-red color and are swollen and numb. In early cases there may be only constant burning and itching. Diathermy followed by vigorous application of the Oudin current is useful in this condition. For the treatment of the toes and foot it is usually best to follow the air-spaced technique and employ luminous heat in addition during a treatment period of at least one-half hour. It is better to keep the amount of current at a strength causing just comfortable warmth. Short-wave diathermy by the coil method offers an alternate procedure. A stimulating dose of Oudin application should follow both for ten minutes. Daily treatment is usually followed by prompt improvement within a few days.

The use of passive hyperemia for chilblains was recommended by

Herxheimer.[14] A constricting rubber bandage is applied at the level of the middle of the humerus or femur, just tightly enough to insure mild venous congestion in the distal part of the limb; this may be left in position for twenty-two out of twenty-four hours. The bandage usually was used only at night and proved sufficient in most cases. In 90 per cent of the cases complete success was achieved in five to seven days; swelling, pains and itching had disappeared, and small ulcers and cracks of the skin had healed. The only remaining sign was redness of the skin, sometimes associated with thickening and wrinkling of the epidermis. The good result was explained by the fact that passive hyperemia forces blood through all potential blood spaces in the limb, including the capillary spaces dilated (and paralyzed) by cold, thus reopening the circulation through them.

This explanation is supported by the fact that passive congestion slightly raises the temperature of a limb, indicating good circulation. If, however, the bandage is applied too firmly and the outflow restricted too much, the limb becomes cold and congestion has no curative effect.

Other measures recommended for chilblains are contrast baths (five minutes in water of 28° to 30° C.; one minute in water of room temperature; then one minute in cold water). Stroking and kneading massage in connection with the baths, hot air or diathermy is also useful. Galvanic baths have also been recommended.

Immersion Foot.—According to Ungley[27] duration of exposure and temperature of water are the most important factors influencing occurrence and severity of immersion foot. During exposure the affected extremities swell and become numb. For some hours after rescue they remain cold; they are pale, blue or mottled and show variable areas of anesthesia. Pulsation is absent from the peripheral arteries—permanently in cases that terminate in extensive gangrene. This prehyperemic stage is followed by a stage of hyperemia, in which the affected parts become hot, red, painful, more swollen and perhaps blistered; in more severe cases patches of gangrene, usually superficial, may appear; damage to nerves declares itself in anesthesia and in motor, vasomotor and sudomotor paralyses. This, in turn, is succeeded by a posthyperemic stage, in which inflammation has subsided, vascular tone has recovered and skin temperature has fallen, but the vessels may be hypersensitive to cold. Late sequels include recurrence of pain, tingling, swelling or blisters; persistence of a cold-sensitive state or of hyperhidrosis, and occasionally circulatory deficiency suggestive of vascular occlusion. With minimal injury patients have no interference with nerve function, and with mild injury they display reversible nerve damage. With moderately severe injury there are irreversible (degenerative) nerve lesions, and with very severe injury, irreversible nerve lesions, usually with gangrene.

The essential principle of treatment is to keep the affected extremities cool and the body warm. The rescued man must be carried, not allowed to walk on damaged feet. Stripped of wet clothing, his body is wrapped in blankets, with the affected limbs exposed. He is given hot drinks, but not left near a fire or in an overheated room. Hot water bottles must not be applied and massage is contraindicated. In the hyperemic stage, dry cooling of the limbs has been accomplished with dry ice-bags, with a current of air from a fan into which cold water is sprayed from a nebulizer or by exposure to room temperature in a cold ward. Webster[28] has achieved good results merely with an electric fan used intermittently and exposure to room temperature at other times. For patients who require long, uninterrupted cooling and who are not intolerant to restriction of leg movements, the mechanical refrigerator might prove useful.

Patients with immersion foot must rest in bed until all swelling has gone and they are able to walk without pain; in severe cases this may be many weeks. Early walking may cause excoriation, blistering or increased swelling. The feet are raised on pillows, exposed to air and kept dry.

White and Warren[29] state that in the early stage of inflammation pain is due to anoxia of the injured superficial tissues and nerve endings. This can be controlled by cooling the legs, lowering cellular metabolism and making the reduced demand for oxygen commensurate with the limited supply which can be supplied by thrombosed superficial blood-vessels.

After inflammation has subsided, aching pain and rigidity of the toes may cause prolonged incapacity in persons with severe injury from immersion foot. Microscopic examination of skin, subcutaneous tissue and superficial muscle (extensor digitorum brevis) show that there is increase in interstitial connective tissue and collagen, involving blood-vessels, muscle fibers and nerves. The last are embedded in fibrous tissue and show endoneural fibrosis also. This pain tends to clear after six to eight months, the period at which collagen surrounding the nerves ceases to contract.

Although there is no effective treatment once fibrosis has developed, much can be accomplished in prevention. Efficient cooling of the injured extremities throughout the early period of recovery and inflammation should do much to prevent fibrosis and prolonged incapacity from pain and rigidity of feet.

Frostbite may be superimposed on immersion foot. In trench foot there is opportunity for combination of the two lesions; a succession of rain, mud and slush would give prolonged chilling sufficient for development of immersion foot and by washing away of skin oils would, with advent of frost, predispose the tissues to frostbite.

Frostbite.—As stated previously at the outset the extent of frostbite cannot be determined and it is impossible to tell whether the lesion will be limited to second degree or go on to necrosis. In mild cases, in which the skin is pale and cold with decreased touch and pain sensation, the patients have a subjective feeling of stiffness, but objectively the tissue is of good consistency. The next stage consists of reactive hyperemia and subjective burning pain. The cases next in severity are those associated with injury to the vessel walls and more severe regression. Lesions in different individuals vary considerably in more severe degrees of frostbite. In some there is true vascular spasm, in others a pure endarteritis, and in some these two factors are mixed. In more severe cases, with absolute anemia, there is no bleeding from a small incision. The tissues are hard and white.

Early treatment must be distinguished from management of late lesions, particularly necrosis. The first consideration is that frostbite produces circulatory stasis, and counteraction of stagnation in peripheral vessels is the prime aim of immediate treatment. There has been extended controversy as to whether rubbing the affected part with snow is right or wrong. Allen[1] states that the folk medicine of cold countries generally favors slow warming of the frozen part: *i. e.*, rubbing it with snow, keeping it for some time in a cool atmosphere and especially avoidance of strong heating. The ethyl chloride spray recommended some years ago must be ranked as equivalent to the popular rubbing with snow. Many physicians recommend gentle kneading of the frostbitten extremity, massaging toward the heart after which the extremity should be carefully wrapped in a clean towel.

Present day medical opinion agrees that a slow rate of thawing should be maintained in frostbite to minimize the metabolic demands of the tissue. This may be accomplished by local hypothermy to the extremity with heat to the remainder of the body. This would aid in counteracting shock and produce a reflex vasodilatation in the affected limb. Bigelow[6] states that the Canadian Army pamphlet suggests immersing the unaffected limb or limbs in hot water to accomplish this. Refrigeration may be continued for one to several days, depending on severity of the lesion. Lewis[18] suggests that controlled thawing may be accompanied by application of cold water at 10° to 15° C., and elevation of the extremities to aid venous return. Sterile dressings should be kept on the limbs and pressure points carefully protected.

Moser,[19] based on extensive wartime experience recommends that except in the mildest cases, active treatment should not be undertaken until the line of demarcation shows signs of forming. In extremely mild cases, in which tissue loss need not be feared, Buerger's exercises appear to yield fairly satisfactory results; for very slight cases, contrast baths also are recommended. Patients should be kept in bed and the frostbitten parts protected carefully from contact with bed clothes with cages. Warm air in the cages was found to be painful and harmful, but a free circulation of cool air was always assured. When once the line of demarcation had formed, ultimate healing was facilitated by the use of a short wave diathermy. Although heat applied to the parts in other ways greatly increased pain, heating of the tissues by short-wave therapy was comforting.

These observations were confirmed by Cignolini[8] and Borini and Matli[7] who report satisfactory results in second and even third-degree lesions with short-wave diathermy applied with air-spaced electrodes, daily treatment from twelve to twenty minutes with an intensity so small that the patient has no sensation of heat for the first six or eight minutes and feels only a slight warmth between the eighth and tenth minutes. Treatments must be systematically administered for weeks, with sterile vaseline dressing applied in the meanwhile. Even in patients admitted with dry gangrene only the mummified part was lost with this procedure.

In the United States Theis[25] and others have seen good results with passive vascular exercise with additional reflex heat. Theis also emphasizes that amputation of gangrenous parts should be delayed until definite demarcation has taken place and the circulation has been sufficiently restored in the surviving tissue.

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CHAPTER XXII

MASSAGE

General Considerations. Massage Movements. Physiological Effects of Massage. Effects of Massage on Pathological Conditions. General Technique of Massage. Uses of Massage.

General Considerations.—Massage is one of the most simple and most useful forms of physical treatment. In its application, the mechanical effect of the technician's hands is transmitted to the patient. The physical elements constituting the different movements of massage are: (1) Contact between the skin of the technician and the skin of the patient; and (2) pressure, the application of a varying amount of mechanical energy to the touching surfaces. The quantitative measurement of the mechanical energy employed is not possible; the individual equation of the technician —the sense of touch of his hands and his alertness in adapting massage movements to the condition treated—play the principle rôle. "Rubbing" by a husky bath attendant has no relation to scientific massage and the effectiveness of the treatment depends by no means on the amount of physical effort expended.

The basis of the intelligent employment of massage is a fair knowledge of anatomy and physiology, and understanding of the pathology of the most common conditions of disease and injury for which massage is used and thorough training in theory and practice of massage, itself. The real leaders and pathfinders in massage were physicians of broad training and experience. More and more physicians have turned to applying massage themselves, especially abroad. In the United States massage is mainly administered by nurses or by specially trained massage technicians. Physicians prescribing massage are expected to give a definite prescription for the type and amount of massage to be given; they should also keep a check-up on the patient's condition and modify their order if indicated.

Massage Movements.—Massage is an art which cannot be taught except by manual demonstration. Students of massage should gain experience by taking massage treatment themselves and by practicing massage under competent guidance. Three main varieties of movements are employed, singly or in combination: stroking, compression and percussion.

Stroking or effleurage is the fundamental form of massage, which is almost instinctive. The mother gently strokes a child's bruised forehead with the palm of her hand in order to relieve pain and to diminish swelling; patients stroke aching parts seeking to ease their painful sensations. Every massage treatment, as a rule, starts with stroking.

In stroking *even* and uniform pressure is exerted along a certain path, by means which are indicated by the topographical characteristics of the region to be treated or by the effect to be produced. Stroking is always exerted from the periphery toward the center, in the direction of venous and lymphatic circulation. On large surfaces it is done with the palm of the hand or with the radial side of the hand, on smaller surfaces with the thumb over the parts hemmed in by bones, while the tips of the fingers may be employed around the knee-, ankle-, elbow- or wrist-joints.

Superficial stroking is used chiefly for the sedative reflex effect and should be performed as if stroking a cat with a slow, gentle, even movement. Simple as it sounds, it is one of the most difficult movements to master and requires much practice. The hands of the operator must be

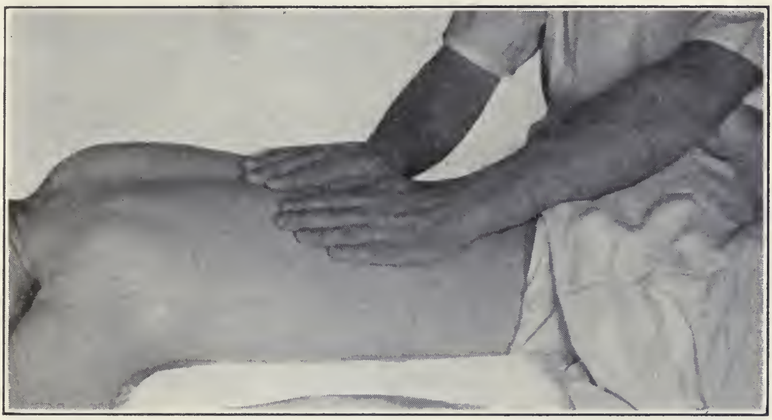

FIG. 257.—Stroking massage to back (first movement).

fully relaxed so that the whole hand and fingers adapt themselves to the contours of the treated area. They should be kept always in contact with the parts, returning lightly to the starting point of the stroke before changing the direction of the stroke. Common mistakes by beginners are: the tendency to scratch the patient at the beginning and the end of the stroke,

FIG. 258.—Stroking massage to back (second movement).

changing the direction of stroking, improper return movement of hands and holding the hands and fingers stiff.

Deep stroking is used principally for unloading engorged veins and lymph channels, as in fractures, sprains, inflamed synovial membranes and in all chronic inflammatory conditions where resorption of an exudate is to be promoted. The pressure exerted should be deep but not heavy, the patient's muscles must be relaxed in order that the veins and lymphatics can be properly emptied.

Fig. 259.—Stroking massage to back (third movement).

The rhythm of all stroking movements should be uniformly slow; it may vary from four to five times in a minute over larger surfaces where it is intended to exert movements of fluids, to 15 to 30 light strokes a minute over smaller areas for sedative effect.

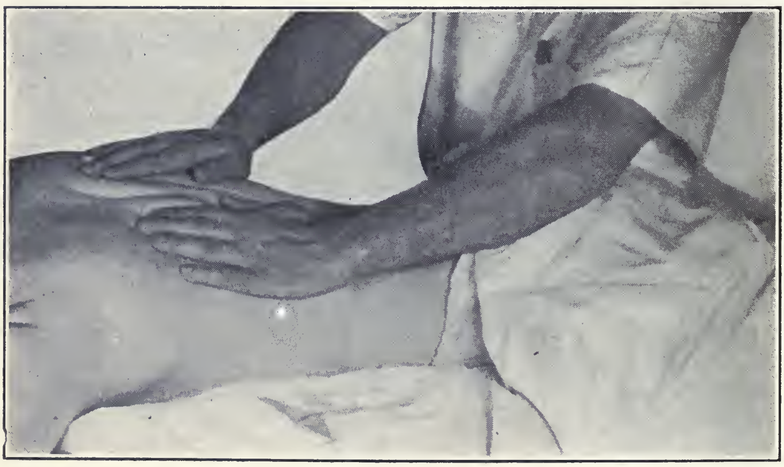

Fig. 260.—Stroking massage to back (fourth movement).

Compression movements are most effective for accomplishing the most frequent object of massage: that of toning up muscles and freeing adherent parts. The principal difference between stroking and compression movements is that in the former the fingers of the operator glide evenly over the skin of the patient, while in compression the skin of the patient is carried along in order to act on the subcutaneous and deeper structures and a variety of pressure is applied. There are two forms of compression movements: kneading and friction.

Kneading is a mixture of grasping and pinching at varying degrees of pressure. The operator picks up the skin and subcutaneous tissue between the thumb and fingers with an amount of force not sufficient to cause pain. In this movement the skin moves with the hand of the operator and the underlying structures are thus massaged under the pressure of the fingers. It is best done by the two hands opposed to one another, by the thumb opposed by the first finger or by the fingers opposed to the palm of the hand. The thumb and fingers are used to reach individual muscles and small groups, such as muscles of the hand, foot, forearm and upper arm. The use of the fingers opposed to the thumb and hand or both hands, the muscles being rolled beneath them and pressed against the bone, is required in treating muscle masses of the thigh and calf. This has the same effect as friction on deep structures and is better for sensitive, easily irritated

FIG. 261.—Kneading of back.

surfaces, the skin moving with the hand like a glove. The movement should always be gradual and proceeding from the periphery inward. The hand should never be removed entirely from the surface; while the pressure is being given, the skin should be moved with the hand and the part squeezed inward or toward the direction of the venous flow. The tissues acted upon by this manipulation are both superficial and deep—skin, fat and muscles of the thorax and extremities, as well as the nerves, arteries, veins and lymphatics.

The main effect of kneading is on the muscles and soft tissues: it serves to stretch retracted muscles and tendons, aids in stretching adhesions and removing waste products from muscle; it also assists the venous and lymph circulation. With a knowledge of the anatomy of muscles the operator begins in the proximal position of the limb and works distally; the motion itself must always be toward the heart or in line with the venous return. The patient's muscles must, of course, be absolutely relaxed.

Friction is a circular form of kneading with pressure against an underlying part of such tissue which cannot be grasped. On a limited area it is best done by the tips of the thumbs, both working in opposite direction; in other parts by the tips of the fingers or one hand open or clenched. Friction by the tips of fingers is used around joints; the entire hand is used over the fleshy part of the thigh, the arm and the lumbar region.

FIG. 262.—Slapping of back.

FIG. 263.—Beating of back.

FIG. 264.—Hacking of back.

Friction is of special value in the manipulation of smaller parts—face, hand or foot and its chief effect is to free adherent skin, to loosen scars and adhesions of deeper parts, as tendons, etc. It should be always preceded or followed by stroking movements and be carried out in the same general direction.

Percussion or tapotement is the most stimulating form of movement and one which is most liable to do damage in overzealous or clumsy hands. We speak of slapping, tapping, clapping and beating according to the position of the hands and fingers delivering a succession of short rhythmic blows to the parts. Percussion movements exert a powerful stimulating effect on the vasomotor system, the skin, blood-vessels and superficial nerves, as well as on the muscles.

Slapping is done with the palmar surface of the fingers, by quick light, alternating strokes, with the wrist relaxed and the fingers immediately rebounding. The mechanical effect of these short strokes is intensively stimulating not only to the superficial capillaries and the sensory nerve endings of the skin but also to the entire nervous system.

Hacking is done with the ulnar side of the hand and the little finger. It consists of rapidly delivered chopping motions from the wrist-joint and the blows may be light or heavy. This movement is fairly difficult to apply skilfully and it must never be given with stiff wrists or with a full arm stroke. When properly applied it exerts a powerful effect on deeper structures and serves to relax muscle spasm, stimulate deep muscle structures and help in breaking up organized exudates.

Two other not so frequently used percussion movements are tapping and beating. *Tapping* is done with the tips of fingers like striking the keyboard of a piano; *beating* is done with the tightly clenched fists striking the body with the back of the second phalanges of the fingers. Beating is the most vigorous form of percussion and is very popular with the bath-rubbers. In scientific massage it is used occasionally for the stimulation of heavy muscles.

TABLE 49.—FORMS AND EFFECTS OF MASSAGE (AFTER REY)

Sedative	Stroking (effleurage)	Acts on cutaneous surface; affects the different nerve endings
	Superficial friction	Acts on skin and subcutaneous tissue and all elements included therein
Stimulative	Deep friction	Acts on all layers of soft tissue and on all elements included therein
	Kneading (pétrissage)	Acts on all soft layers; kneading of muscle *par excellence*
	Percussion	Acts on soft parts, causes stimulation of muscle which responds with a mild contraction

Physiological Effects of Massage.—The variety of massage movements exerts manifold effects on the structures of the body and upon the general organism.

Upon the *skin* massage exerts a mechanical stimulation, its immediate effect being a dilatation of the capillaries, accompanied by a subjective feeling of warmth. This hyperemia is only temporary, disappearing as soon as the reaction of the capillary vessels ceases. Massage exerts a cleansing effect on the superficial layers of the epidermis, dead cells are removed, the contents of sebaceous ducts emptied and thus sebaceous secretion is facilitated. The movement of fluids in the skin is stimulated and after frequent massage the skin becomes softer and more moist.

The skin as the principal organ of touch usually responds gratefully to the massage movements of stroking and friction; perhaps no sensation is felt so pleasantly as skilfully applied massage.

In the *subcutaneous tissue* massage also promotes the movement of fluids and loosens the elastic layer, thus making the skin itself more firm. As a result the skin moves more easily and skinfolds and wrinkles due to tenseness of the subcutaneous structures gradually disappear. In spite of its popularity in "beauty culture," massage does not remove the wrinkles of old age, neither can it disperse nor squeeze out lumps of fat under the skin. Only when the entire organism is affected by regular massage and exercise does the subcutaneous fat begin to disappear. In other words, fat accumulation under the skin cannot be affected by massage except indirectly through increasing general body metabolism.

The *blood-vessels* of the skin and subcutaneous tissue can be effectively emptied by massage. In persons who are not too fat the superficial veins can be seen collapsing and filling up again as their contents are pushed along by hand. By assisting the venous return, the blood column in front of the arterioles is decreased and the blood can pass through the capillary circulation more readily. As a further result a larger supply of arterial blood will be forced through the part under treatment. The same pressure acts upon the lymphatic vessels, causing a more rapid absorption of nutriment and of pathological products through their walls. Thus the links in the chain of physiological phenomena produced by massage are arterial stimulation, active hyperemia, more active nutrition, secretion, excretion and absorption, in fact more rapid and more thorough metabolism and increased functional activity in the part or parts subjected to massage. It has been shown that after massage there is an increase of red blood cells in the superficial vessels amounting to from 40 to 50 per cent.

Muscles are among the chief objects of treatment by massage. Physiological experiments are on record proving that massage applied to a resting muscle increases its power for work and retards fatigue, it prevents the accumulation of fatigue products in a muscle and furthermore it enables the muscle to do more work than can a corresponding amount of rest. Through the active hyperemia brought about, massage stimulates the nutrition of muscle tissue and restores the tone and strength of muscles if they have weakened from lack of activity, local or general. Percussion movements may cause local muscular contraction but this does not replace active muscular exercise because no work is performed.

In the *nervous system* gentle massage over a healthy nerve by its stimulative effect causes irritability and pain. In aching nerves mild pressure increases the irritability, firm pressure lessens it and may eventually suspend it altogether.

General massage affects the circulation of the entire body by speeding up the blood flow in the soft parts, the skin, subcutaneous tissue and muscles. The capillary blood-vessels become dilated and more than the usual number open up, thus there is an increased circulation of blood and better nutrition of the parts without exerting the heart. There is also a corresponding increase in general metabolism. Many persons go more easily to sleep after a general body massage. There is also usually an increase in urinary excretion but no marked alteration in the rate of excretion of the various urinary constituents.

Effects of Massage on Pathological Conditions.—The influence of massage upon pathological processes is no less decided than upon physiological ones.

Chronic inflammatory changes in the tissues caused by trauma or infections and their after-effects, local edema, indurations and infiltrations, extravasations of blood, scars, adhesions in the skin, tendon sheaths, in muscles and around joints are favorably influenced by appropriate massage movements: resorption is accelerated, adhesions are freed and indurated parts are softened. This is due to the speeding up of the movement of the venous and lymphatic circulation, to the pushing effect on the extravasated fluid and to the mechanical stretching of the strings and bands of connective and fibrous tissue. Skilful massage will prevent or minimize scars and adhesions in the skin as well as in deeper tissues within reach of massage movements.

In conditions of muscular weakness which are due to disuse, general systemic inactivity or exhausting disease, massage will help to keep up muscular tone and prevent further atrophy of the muscles. In real paralysis following peripheral nerve injuries or anterior poliomyelitis massage will *not* restore muscular power and if roughly done it will rather increase muscular atrophy and diminish muscular tone. Very gently superficial stroking, preceded by mild heating, may be applied after the acute stage; it will stimulate the venous and lymphatic circulation of the limb and carry away some of the waste products. In this way properly applied massage will induce better nutrition and may delay muscular atrophy.

Edema of the skin and subcutaneous tissue due to circulatory changes can be locally dispersed and the work of the heart relieved by combined local and general massage; the flow of blood becomes accelerated without straining the heart, edema, cyanosis and shortness of breath are improved. In chronic circulatory diseases due to a weak heart muscle, massage is a most beneficial measure at the bedside.

General Technique of Massage.—Rooms for massage should be light and kept at an even temperature, which is most comfortable to patients somewhere between 70° to 75° F. The patient must be comfortably relaxed in either sitting or recumbent position, lying down being generally preferable because it insures more relaxation. For institutional treatments special massage tables are essential; they should be 30 inches high, 2½ feet wide and be covered with a good mattress without springs. When patients are treated in the sitting position—for treatment of the head, neck, shoulder and upper extremity—suitably placed pillows should insure comfortable relaxation of the parts. Parts not under treatment should be covered.

The patient's skin should be clean and careful note should be taken of wounds, small abrasions and inflamed skin follicles; massage should never be applied over such parts.

Most massage technicians use some lubricant as talcum powder or a fatty substance, vaseline, albolene or olive oil. No hard and fast rule can be laid down, for the choice of lubricant depends on the skin of the patient and his condition and on the skin of the operator. Too much lubrication interferes with good friction which is essential for efficient massage. Over a hairy skin powder should be used because oily lubricants frequently cause inflammation of hair follicles. Powder is generally preferable in fractures and traumatic conditions and also for operators whose hands are moist. For a dry and scaly skin a fatty lubricant is more suitable. The remnants of an oily lubricant should be removed by alcohol after massage and powder should be rubbed off with a towel or with soap and water.

Preparatory to massage the warming up of the part or the entire body by radiant heat or hot bath insures softening of the skin and relaxation of the muscles. Excellent results are accomplished by the practice in certain spas of massaging stiff joints under a hot shower (Aix-le-Bain massage). This corresponds with the hydromassage technique now so extensively employed in treatment of wartime and industrial traumatism.

The average *duration* of a local massage to one part should be from ten to fifteen minutes when massage alone is used and from five to ten minutes if other forms of physical therapy are employed. If several parts are to be treated at one sitting each part ought to be treated as if it were the only one affected. General massage treatment should take about one hour and this time may be proportioned in the following sequence: legs, fifteen; arms, ten; chest, five; abdomen, fifteen; back, fifteen minutes. It is generally advisable to begin with short and mild treatments and continue according to the condition and reaction of the patient.

No massage treatment should be painful or bring on pain as its after-effect. Neither should it exhaust nor irritate a patient. A rest period should follow every massage, the length of which may vary from ten minutes to one hour, according to the duration and extent of the massage or other physical measures applied.

The frequency of massage depends on the condition treated. In acute traumatic or painful conditions, as a rule, daily treatments are administered.

Uses of Massage.—Massage with its manifold effects upon the structure of the body and upon the general system offers valuable aid in the treatment of many disabilities and diseased conditions. Until the present-day large variety of physical measures, many medical men considered massage and heat all there was to physical therapy. Some of the older text-books on massage contain a massage prescription for practically every disease condition known. At the other extreme were medical men who practiced all kinds of electrical and light treatments and never employed massage. Nowadays in the practice of physical therapy by competent physicians and in institutional work, massage is regarded as an essential part of routine treatment, especially where hand power is cheap. At the same time, it is realized that massage effects may be produced in many conditions by other mechanical measures, more convenient and more efficient. Sherman[3] and Smart[4] have stated that in the treatment of traumatic conditions, electrical units producing graduated muscular contractions have satisfactorily replaced massage. (See page 176.)

There can be no doubt that the well-controllable mechanical effect of low-frequency currents, of the static wave current, static sparks, and the gentle mechanical action of the Oudin application and the hot whirlpool bath offer effective alternates of some of the massage movements. For the protection of the nurse or technician, these measures should be substituted for massage by the prescribing physician when it is desirable to avoid physical contact with a patient. For the general rank and file of patients and for emergency and many home treatments, the skilled massage technician will always remain a desirable member of the medical auxiliary personnel. No clinic and no physician employing physical therapy can do very well without massage.

The generally recognized scope of massage in the variety of medical and surgical conditions is as follows:

Traumatic Conditions.—The pathfinding studies of Lucas-Championnere, of Paris, and J. B. Mennell,[2] of England, have shown that massage movements may be successfully employed for the relief of pain and spasm, even in the most acute stages of an injury. Such treatment must be given by an experienced physician. The patient is placed in a comfortable position, with the injured part fully supported and relaxed and slow regular stroking movements—at a rate of 10 to 12 a minute—are made over it without touching at first; gradually light contact is made, with the part of the operator's hands fitting it uniformly. It is stated by Heald[1] that after 12 to 250 movements the parts become fully relaxed, due to "local hypnosis." There is no mystery to these movements; if the patient's confidence is won and he relaxes the spasm with which the injured parts are protected, no pain will be caused by such massage.

Storms[5] believes that massage is properly used for detection and relief of muscle spasm. If a muscle is subjected to greater strain than it can stand, some of its fibers tear. Pain, swelling and other signs of inflammation of the muscle appear, and the entire muscle or part of it goes into spasm. This is painful and may last for hours or years. If it persists for long, part of the muscle involved destroys a portion of its substance by its continuous contracture, and there is replacement by scar tissue, resulting in fibrosis of the muscle, with its subsequent effects. Spasm can at any time be felt by the examining fingers and it is the direct cause of the pain for which relief is sought. It should be detected by palpation and treated at once. Storms recommends a kneading stroke and occasionally some firm effleurage. In an acutely swollen, sprained ankle, firm, slow effleurage is required to drain fluid out of tissues and engorged veins; light stroking would only irritate. In kneading of the spasm, the cushions of the finger-tips or the balls of the thumbs do not slide over the skin; instead they hold position on the skin, the short stroke being made possible by the loose connective tissues. The direction of the kneading stroke is always parallel to the muscle fibers, never across, to keep the discomfort at a minimum; the power of the stroke is adjusted to the patient's tolerance. As soon as the spasm begins to soften, treatment should be stopped for that day. Otherwise the spasm may tighten up, not to soften again during the treatment, and may produce more pain than there was at the beginning of treatment.

After the disappearance of the spasm and pain of the initial stage, regular massage treatment may be started. It is advisable, as a rule, to precede it by local heat application as already stated. The injured part must be carefully supported and stroking movements are applied with increasing firmness and gradually including a wider area. Additional massage movements such as deep kneading are applied according to the site, extent and nature of the injury.

Massage is indispensable as part of the efficient treatment of fractures, dislocations, stiff joints and other traumatic conditions. In these conditions massage is usually combined with suitable exercises and preceded by thermal measures. The details of indications and technique will be presented in chapter on traumatic conditions.

Arthritis and Rheumatic Conditions.—In arthritis and rheumatic conditions, massage serves to improve circulation in the neighborhood of affected joints, and soft structures (chiefly the muscles) and to compensate to a certain extent for the lack of muscular inactivity due to the disabling condition. It should be preceded by heating by hot water, lamps or diathermy. For further details see chapter on chronic arthritis.

Disorders of the Digestive Tract.—Atonic conditions of the gastro-intestinal tract, especially chronic constipation, can be considerably benefited by appropriate massage. There are many forms of manipulations recommended; as a rule, the simpler the technique the more efficient it becomes, as long as it follows physiological principles. All massage movements to the abdominal wall must be applied at a slow rate, about twelve movements a minute, because the peristaltic wave travels slowly and a stimulus applied before relaxation follows a contraction may cause a spasm. Too much pressure must also be avoided, because through a relaxed abdominal wall, pressure is directly transmitted to the viscera. Finally, massage movements must be carried out in the direction of the movement of the intestinal contents, starting with gentle stroking, beginning at the ascending colon, continuing along the hepatic flexure, the transverse colon and sigmoid flexure until the whole abdomen is relaxed. This should be followed by gentle kneading applied in the same direction. For further details see chapter on abdominal conditions.

Disorders of the Nervous System.—In peripheral nerve injuries and anterior poliomyelitis, the only favorable effect that can be expected from massage is to improve nutrition by stimulating circulation. In flaccid paralysis, the lack of muscle tone carries the danger of paralytic dilatation by excess manipulation of the small blood-vessels, thereby adding insult to injury. Hence in paralysis, massage must be given only in a most gentle form; one should never squeeze or press paralyzed muscles against bones. Too long treatments must also be avoided, because they exhaust the muscles and increase atrophy. For details see chapter on affections of the peripheral nervous system.

In spastic paralysis there exists an increase of muscle tone and massage is employed to minimize atrophy and together with muscle re-education to prevent contractures and joint stiffness. Massage should begin by slow and even stroking, continued with gentle re-educational exercises. For details see chapter on affections of central nervous system.

In organic diseases of the central nervous system, general massage is often useful for its tonic and soothing action; the details of treatment must be regulated according to the patient's condition.

Cardiovascular Conditions.—In chronic decompensated heart conditions systematically and cautiously applied general stroking and gentle kneading may be of considerable aid in returning the stagnant tissue fluids, relieving the edema and preserving muscle tone. General massage also aids by the increase of kidney function. In acute cardiac decompensation and in far-advanced chronic conditions massage promises no such help. For details see respective chapter.

Other Systemic Conditions.—In convalescence, secondary anemia and in all chronic disease conditions which keep patients in bed for a prolonged period, massage can be effectively applied for general stimulative purposes. With treatments carefully administered, daily or every other day, patients show improvement in their general well-being, sleep, appetite, color and muscle tone. Hence, general massage is an important treatment measure in these conditions. In obesity regulation of diet and systematic exercise accompanied by a judicious amount of general massage will help by the effect on the general organism but not by local mechanical action. For details see Chapter XXV.

Contraindications to Massage.—Wounds, skin eruptions and inflammatory processes in or underneath the skin exclude the use of massage to the affected parts. Acute inflammatory conditions anywhere in the body, but especially in the abdomen, are also contraindications, likewise tumors and tuberculous joint affections. No massage should be given to the abdomen and lumbar region during menstruation and none to the abdomen during pregnancy.

In the acute stage of local inflammatory and irritative conditions of peripheral nerves, neuritis and neuralgia, massage is as a rule harmful, for even mild stroking may bring on a violent increase of pain.

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CHAPTER XXIII

EXERCISE

By H. J. BEHREND, M.D.

ASSOCIATE PHYSICAL THERAPIST, HOSPITAL FOR JOINT DISEASES; VISITING PHYSICAL THERAPIST, WELFARE HOSPITAL, NEW YORK CITY

General Considerations. Physiological Effects. General Technique. Indications. Exercise in Various Conditions. Circulatory System. Respiratory System. Gastro-intestinal System. Nervous System. Conditions of Bones and Joints. Arthritis and Rheumatic Conditions. Peripheral Vascular Diseases. Posture. Underwater Exercises.

General Considerations.—The term "Corrective Exercises" is applied to certain gymnastic movements which aim to improve the function of the more or less weakened body or parts of it. We therefore must distinguish between general corrective gymnastics and partial corrective exercises as given, for instance, in the treatment of regional muscle conditions or of diseases of the bones, joints and nerves. It is the latter group the general practitioner is most likely confronted with and the necessity of his being acquainted with the fundamentals of this form of therapy becomes apparent. He should be able to prescribe corrective exercises intelligently and to supervise their execution if performed by nurses, technicians or other assistants.

Two groups of corrective exercises are generally recognized, namely passive and active exercises. In *passive* exercises the operator or a mechanical device performs the movements of the body or parts of it, and the patient remains inert sitting comfortably or lying down in a relaxed position. This form of exercise is widely used for the treatment of stiff joints, contractures, scar tissue, and muscular paresis due to central or peripheral nerve lesions. *Active* exercises are performed by the patient himself. He either uses his muscles freely or against an opposing resistance. This requires the full coöperation of the patient. Two forms of resistance exercises are possible: Either the operator gives the resistance while the patient goes through the movement, or the operator moves every part of the body with the patient resisting. Active exercises will develop muscle strength and are therefore indicated in all cases where muscle strength has been impaired. Under systematic active exercises muscles which became atrophic because of inactivity, for instance after immobilization, will improve as will those weakened because of an impaired nerve supply. As compared with massage exercise is the only method to develop muscle strength. Massage alone will never "work up" a muscle. However, it will prepare the muscles for exercises by improving the local circulation and metabolism. The efficiency of the muscle tissue is increased by massage. The combination of exercises and massage is therefore well indicated and should never be neglected.

Physiological Effects.—Exercises exert their principal physiological effects on the muscles, nerves and joints.

A *muscle* carried through any form of exercise will respond with an active hyperemia. The circulation is improved not only because the capillaries and small arteries dilate, but also on account of the mechanical effect on the small veins. Muscular contraction produces a compression on the venous system resulting in an enhanced reflux of the venous blood toward the heart. This increase of circulation will remove faster the products of fatigue, mainly lactic acid. Lactic acid is a product of the normal glycogen metabolism in the muscle. It is produced during muscle activity and is eliminated by combination with oxygen during the rest period. It is therefore essential to interpose sufficient intervals of rest and relaxation during exercises. The sensation of fatigue normally protects the muscle; its disregard results in overstraining of the muscle. In addition to the production of lactic acid a depletion of its protein reserves will weaken the muscle tissue. Weakening of muscle tissue means decrease of muscle tonus.

Diminished muscle tone results in a slower response to stimulation. If a patient under treatment shows sign of fatigue or increased muscle flabbiness, this should call for immediate termination of the exercise and for interpolation of a rest period which should last, at least, ten minutes.

In addition to the improved circulation exercise affects the muscle tissue itself. Continued training of a muscle increases its bulk, whereby the size of the individual muscle fiber is enlarged—by no means their number. In atrophy due to inactivity or nerve injury or disease the bulk of the muscle diminishes until, in severe cases, the muscular tissue almost disappears. Corrective exercise may counteract some of this tendency.

The physiological effect of corrective exercises on the *nervous system* results in an improvement of the coördination of the neuromuscular element. In disorders of the central nervous system exercises will stimulate and re-establish peripheral nerve conductivity. For instance in hemiplegia early instituted exercises will keep up the nutrition of the muscles and will prevent the development of contractures and deformities unless the central lesion has caused an irreparable damage. Even more important are exercises in lesions of the peripheral nervous system (neuritis, Bell's palsy, etc.), which are associated with degenerative changes of the muscles, skin and bones.

In the physiological effects on *bones* and *joints* we deal with an improved circulation, which leads to a mobilization of stiff joints, their capsule and pericapsular tissue. The re-education of the muscular activity re-establishes the normal function and position of the joint if not ankylosed or otherwise destroyed.

Besides the effects on muscles, nerves or joints the general stimulative effect of exercise on the body is of utmost importance for it will affect favorably the cardiovascular and respiratory system as well as metabolism.

Although exercises primarily will put a strain on the heart, circulation and respiration, this should later result in a strengthening of these organs. The exercises therefore have to be given in increasing doses according to the individual constitution and disposition. This requires experience and strict observation of the reactions of the patient. The blood-pressure rises and the pulse-rate is increased. This fact is used as a tolerance test for exercises. If the blood-pressure does not rise and the pulse-rate does not return to normal after one to two minutes of rest, it may be assumed that the circulatory system deserves special attention before starting exercises, and that the amount of exercises given must be increased very slowly. Diseases of the heart are by no means always contraindications for carefully applied corrective exercises. On the contrary, the strength of the heart muscle increases parallel with the development of the voluntary musculature.

Since the activities of the heart and lungs return to normal rapidly, and since it requires much more time for the metabolism of the muscle to be restored to its usual level, the interposition of the rest periods mentioned above is essential. The rest period is best filled out with observation of the patient's breathing technique and its improvement. Control of the respiration during exercises is of utmost importance. Breathing exercises must be interposed frequently during the rest period. Correct breathing will produce relaxation. Shallow or incorrect breathing will produce tension. It affects the circulation and the sympathetic nervous system through the respiratory center. Tension is caused in all muscle groups participating in respiration, because these muscles do not relax sufficiently during exhalation. A certain residual tension remains in these muscle groups which, reflexly, is transmitted to other muscles and if not removed will establish a vicious circle because circulatory changes will occur due to decreased negative pressure in the thorax which impairs venous return. Shallow breathing combined with impaired circulation reduces oxygenation of the blood, the most important factor in restoring the function of a fatigued muscle to normal. The importance of breathing exercises therefore becomes apparent. They will increase the mobility of the chest, further thoracic respiration and will relieve abdominal stasis. Systemic deep breathing will cause a fall of blood-pressure in cases of hypertension and has widely been used for the treatment of this condition.

General Technique of Exercises.—All orders for corrective exercise have to be given by the physician in detail. It is not advisable, for instance, to prescribe just exercises for a certain joint or extremity without specifying the movements wanted. An exact diagnosis is essential before starting treatments. During a course of treatments the condition of the patient has to be controlled frequently and the exercises have to be adjusted according to progress.

There has been a great variety of exercises suggested for corrective treatment. Because of the large number of conditions that respond to corrective exercises many systems of exercises have been developed. Their value as an unrestricted method is questionable and its indiscriminate use often dangerous.

For better understanding, however, one may classify all exercises into two major groups:

(*a*) Local exercises for the treatments of a specific part of the body.
(*b*) General exercises.

Local exercises are employed in post-traumatic, inflammatory or degenerative conditions in order to re-establish normal function. General exercises are chiefly employed in postural conditions and for recreational purposes.

(*a*) *Local Exercises.*—No definite technique can be described generally for any traumatic, inflammatory or degenerative condition which, for instance, affects the muscles, ligaments, bones or joints of the extremities.

All depends on the individual case. It is, however, important that all movements possible with regard to the functional structure of the joint be carried out.

Fig. 265 Fig. 266

Fig. 265.—Passive exercises of fingers.
Fig. 266.—Active exercises of fingers.

Fig. 267.—Passive flexion of wrist.

To obtain the greatest benefit from local corrective exercise one must have a clear conception of the basic principles involved. In a neutral position of a joint, or in a part at rest, the muscles controlling movement are in a state of balanced tone. Due to the principle of reciprocal innervation, movement of a joint involves increase in tone which results in contraction of one muscle or group and a corresponding decreased tone or relaxation of the opponents. Increased tone amounting to spasticity without the possibility of the reciprocal relaxation noted above will nullify efforts to administer proper corrective exercise. In such cases it is of prime importance to secure relaxation by some means. In cases of decreased tone, muscle weakness or atrophy for any reason, it is essential to avoid undesired training of any normal muscle group. The affected muscles must be singled out and training directed to them exclusively. If necessary, fixation of the parts may be required so that the affected muscles will be sure to perform as desired.

In treating the upper extremity, the hand, elbow or shoulder joint must be well supported and the exercises are given with the patient either in the sitting or lying position. To exercise the fingers, for instance, the patient sits on a chair and supports the hand on a small table on which a firm small pillow is placed. The operator holds with one of his hands the patient's wrist in fixation and then moves the joints of all fingers in all directions which are physiologically possible. (Figs. 265–267.) The knowledge of the average amplitude of the principal active movements is necessary to appreciate the limitation in the range of motion of a joint. These measurements can be taken with a simple device consisting of jointed arms and a protractor scale; one arm is fixed at zero of the scale while the motion of the other arm shows on the scale the degree of motion. For correct reading of progress regular charting of joint motion is indispensable. The average range of joint movements is shown in Table 50.

TABLE 50.—AVERAGE RANGE OF JOINT MOVEMENTS

Shoulder:
- Abduction—zero to 160°. Range—160°.
  - (From zero to 80° is the range in the shoulder-joint itself, while from 80° to 160° movement is made by elevation and rotation of the scapula.)
- Flexion—zero to 180°. Range—180°.
- Extension—zero to 45°. Range—45°.
- Internal rotation—zero to 80°. Range—80°.
- External rotation—zero to 45°. Range—45°.

Elbow:
- Flexion to 45°. Extension to 180°. Range—135°.
- Pronation—zero to 90°. Range—90°.
- Supination—zero to 90°. Range—90°.

Wrist:
- Flexion to 100°. Extension to 240°. Range—140°.
- Abduction—zero to 35°. Range—35°.
- Adduction—zero to 50°. Range—50°.

	Metacarpo-phalangeal joint	*Proximal interphalangeal joint*	*Distal interphalangeal joint*
Fingers: Flexion.			
2d, 3d, 4th and 5th fingers	85°	110°	75°
Thumb	70°	85°	

Hip:
- Abduction—zero to 45°. Range—45°.
- Adduction—zero to 45°. Range—45°.
- Flexion to 60°. Extension to 180°. Range—120°.
- Hyperextension from 180°. Extension to 135°. Range—45°.
- External rotation—zero to 60°. Range—60°.
- Internal rotation—zero to 30°. Range—30°.

Knee:
- Flexion to 45°. Extension to 180°. Range—35°.

Ankle:
- Dorsiflexion—90° to 135°. Range—45°.
- Plantar flexion—90° to 70°. Range—20°.

It is essential that passive and active exercises combined are given in every session. The operator begins with gentle passive exercises and then instructs the patient to move the joint actively first without and later with resistance which will be either concentric (the operator gives the resistance) or eccentric (the patient resists to the movement). Flexion, extension, abduction, adduction and rotation is thus performed successively.

The principles discussed for the treatment of the upper extremity are also applied in treating the trunk, the head or the lower extremities.

Care has to be taken that the patient does not become too fatigued. The average duration of a session should be fifteen to thirty minutes after which the patient should rest quite some time.

Fig. 268.—Convalescent group exercise in ward.

In order to carry out *general exercises* successfully a definite program has to be planned to avoid the exercises from becoming boring and monotonous. The condition of the heart, lungs, kidneys, bones and joints must be ascertained by a complete medical examination, and the simple circulatory test described will prove very useful and can be easily performed.

Fig. 269.—Convalescent group exercise outdoors.

In the untrained or the weak the exercises have to be graded beginning first with the patient lying down and later in the sittingor standing position. The temperature of the treatment room should be about 70° F., and the patient's clothing should be adapted to the work. Before beginning the session the patient should empty the bladder and bowels and clean his nose thoroughly. The orders should be given in a determined, low voice, and every movement must be carried out exactly as ordered and repeated slowly and precisely until properly done. Here again it is important to interpose sufficient rest periods so as not to fatigue the patient. Breathing exercises should be inserted frequently for the reasons already given. The duration of an individual session should be thirty-five to forty-five minutes at most, including rests during the time, and a rest of fifteen to thirty minutes at the conclusion of the treatment should follow. Overtiring has to be avoided. The patient should feel relaxed and invigorated at the end of the treatment. For the average purpose no apparatus is necessary. The use of apparatus may even be dangerous. Nothing can take the place of active exercises.

For reconditioning group exercises have a definite advantage. They are used for the rehabilitation of the wounded of the Army and Navy. Figures 268 and 269 demonstrate some group exercises as used in the reconditioning program of the Army Air Forces.

EXERCISE IN VARIOUS CONDITIONS

Circulatory System.—The circulatory system responds most readily to graduated gymnastics. The heart muscle can be trained to exertion and compensation.

The resistive exercises of Schott and Oertel are based upon the graduated resistance given to the patient's movement, thus making the heart increase its work as it improves after each exercise; the heart-rate must be allowed to fall to its previous count or even below before continuing. The Schott exercises are principally for mitral and aortic insufficiency.

Oertel has introduced graded walking exercises to increase the efficiency of the heart muscle. The patient has to take a walk first on the level ground for a few minutes; later depending upon the progress and reaction of the heart, the time factor is increased and walking on hilly territory is added.

Systematic exercises have been recommended for the treatment of arterial hypertension. They will procure relaxation and decrease of peripheral resistance. For further details see Chapter XXIV.

Respiratory System.—The physiological effects of *breathing exercises* have been discussed. For performing correct breathing exercises the patient is placed on a cushioned table in a comfortable dorsal recumbent position. He first exhales blowing through the pursed lips. The patient must now rest quietly and wait until natural inspiration occurs. This inspiration must be smooth without conscious forcing of the chest or abdominal walls into certain positions. This exercise should be performed several times and is to be supported by movements of the extremities, for instance, raising, lowering and stretching in accordance with inhalation or exhalation. To establish a complete breathing act and relaxation we must examine the patient to determine whether any muscles are embarrassed in their function because of impaired antagonist muscles or obstruction in the respiratory tract. Particular attention must be paid to the lateral muscles of the chest and those of the back. In many cases unusual tension of the

FIG. 270

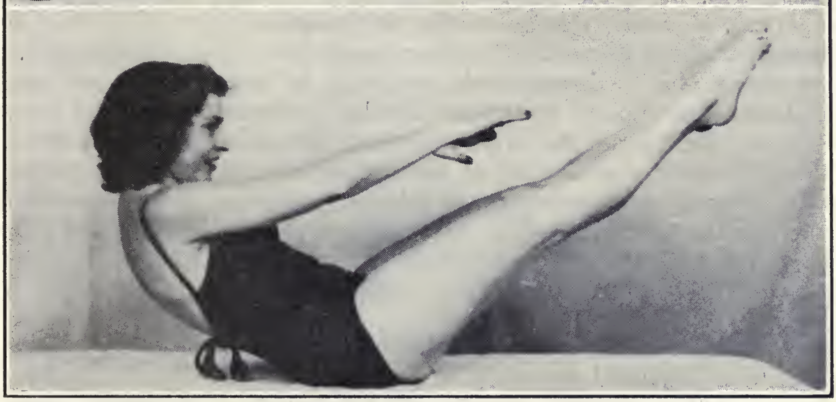

FIG. 271

FIG. 270.—Exercises for abdominal muscles I, single leg raising.
FIG. 271.—Forceful contraction of abdominal muscles, double leg raising.

FIG. 272

FIG. 273

FIG. 272.—Exercises for abdominal muscles II. Abdominal muscles relaxed; lumbar lordosis present.
FIG. 273.—Abdominal muscles contracted; back is flattened.

muscles controlling the costal margin is observed. This can be remedied by suitable training to increase the lateral excursion of the ribs. In some cases of emphysematous type or barrel chest, uneven excursion of the chest wall may be noted. Movement of the lateral portions may be excessive. Equalizing the movement of the chest cage will often clear up symptoms of cardiac involvement which, thereby, prove to have been functional.

The *indications* for breathing exercises are chronic bronchitis, emphysema and pleurisy; pleuritic adhesions especially will be influenced favorably. In the treatment of bronchial asthma they will help restore elasticity of the thorax, which has been impaired by decreased mobility and here also play an important rôle in relaxing the patient.

Gastro-intestinal System.—Conditions such as constipation, flatulence, visceroptosis, obesity, hemorrhoids, etc., may be helped by general and special exercises and, in particular, by the development of good body mechanics. Here again the breathing exercises will increase the activity of the diaphragm thus massaging the abdominal organs and promoting the flow through the portal vein and inferior vena cava. Strengthening of the abdominal wall will have a direct influence upon the liver and gallbladder and will increase intestinal peristalsis where required. Some typical exercises for the strengthening of the abdominal muscles are shown in Figures 270–273.

Nervous System.—There is a large field for therapeutic exercise in the organic and functional disorders of the central and peripheral nervous system. Acute anterior poliomyelitis, hemiplegia, Bell's palsy, tabes dorsalis, neuritis among the organic and chorea, neuralgia, neurasthenia and the neuroses among the functional disorders, will call for special exercises to teach alertness, steadiness and coördination in the process of muscular re-education.

Rest and relaxation must frequently interrupt these exercises, for fatigue is the great foe of nerve tissue.

Injuries of Bones and Joints.—In the after-treatment of fractures, dislocations and sprains it is impossible to give other than general directions. Gentle heat and stroking massage of the muscles controlling the movements of the joint will first be instituted. As soon as the surgeon permits exercises will be started. They will first involve joints distal to the injury, as the fingers, in cases of injuries to the wrist or arm, the toes, in injuries to the foot, leg, thigh, etc. These exercises should be active because these alone are going to restore function and will prevent too great damage. Passive motion has usually no place in fractures, but is of value in sprains and dislocations after the inflammatory stage has subsided. Early institution of exercises will secure better results because unnecessary fixation, adhesions and contractures are being avoided. Where they are present, their mobilization will be facilitated.

Early, carefully considered postoperative exercises are both prophylactic and regenerative. Thrombophlebitis and embolism are less likely to occur. For further details see Chapter XXIX.

Peripheral Vascular Disease.—For the treatment of peripheral vascular diseases Buerger's exercises and the use of suitable apparatus have been recommended and is fully discussed in Chapter XXIV.

Arthritis and Rheumatic Conditions.—In arthritis and in rheumatic conditions therapeutic exercises are being applied for many reasons. Function of the joints must be maintained and improved. Involved muscle groups must be strengthened and deformities must be corrected. General improvement of the circulation is in order and body mechanics must be restored to normal in order to guarantee a smooth and coördinated functioning of the bones, joints and muscles.

In applying corrective exercises it is necessary to differentiate between the infectious rheumatoid and the degenerative osteo-arthritic conditions. Great care should be taken not to aggravate or activate the first group by too strenuous treatments. In conjunction with rest and gentle massage, passive exercises should be given in order to keep up a normal range of motion and to avoid the formation of adhesions.

These exercises should rather be given several times daily instead of exhausting the patient in one too excessive session. Repeated exercises with interposed rest periods constitute the best training and prophylaxis for an acutely diseased arthritic joint.

Fig. 274 Fig. 275

Fig. 274.—Exercise for stiff shoulder in supine position:
Fig. 275.—Exercise for stiff shoulder in sitting position.

In chronic degenerative or osteo-arthritis active and passive exercises in combination with all tools and equipment of physical therapy are indicated. The technique depends on the individual case in accordance with all principles outlined at previous occasions. Exercises under water have a wide field of usefulness in these cases. Light work will help to keep up the motion and general upbuilding will help considerably.

There are three arthritic conditions which the general practitioner is frequently confronted with where corrective exercises are especially helpful. The treatment of the arthritic hand has been described. (Figs. 265–267.) For the painful shoulder corrective exercises are of extreme importance. The lesions most frequently found here are bursitis, arthritis and periarthritis. In the acute stage exercises are definitely contraindicated. In the subacute stage or in the more chronic phases carefully administered exercises are of the greatest value in preventing the formation of adhesions and limitation of motion.

Treatment of the stiff shoulder by manipulation, under anesthesia, is only of very limited value. It is in these cases that conservative corrective exercises are very helpful. After application of heat and massage exercises are given with the patient first in the supine position, lying flat. The arm is moved forward, upward and then carried backward until further move-

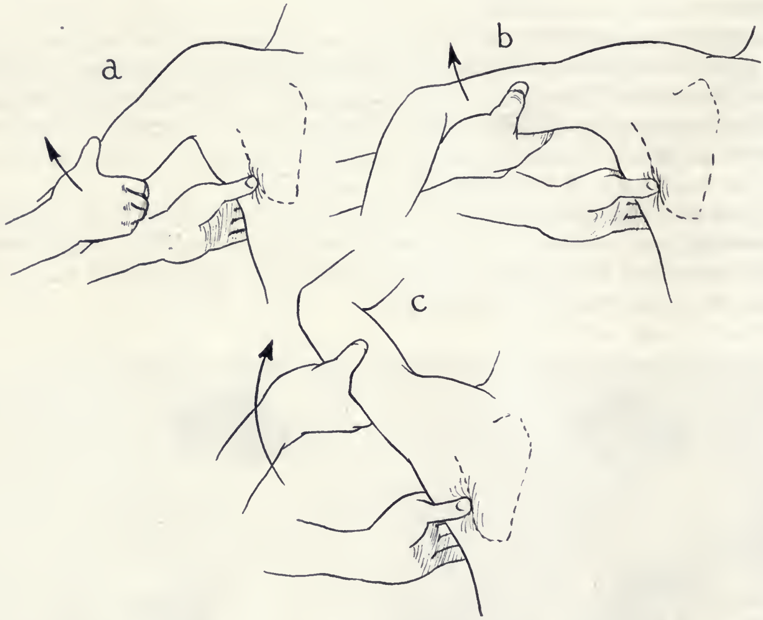

Fig. 276.—Passive exercise of shoulder to increase range of lateral abduction. Seapula held firmly to prevent rotation of the shoulder girdle. (Courtesy of Drs. G. E. Haggart and C. R. Carr and New England Jour. Med.)

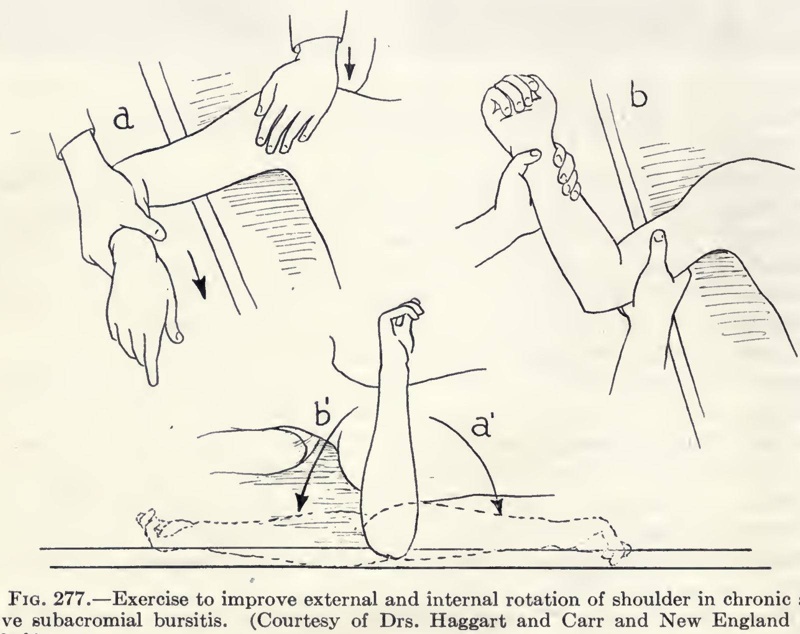

Fig. 277.—Exercise to improve external and internal rotation of shoulder in chronic adhesive subacromial bursitis. (Courtesy of Drs. Haggart and Carr and New England Jour. Med.)

ment is limited by pain. It must be carried slightly beyond this point, and so held for a few seconds (Fig. 274). The arm is then carefully and slowly restored to the neutral position at the side and left so until pain has subsided. In the second maneuver the arm is carried into abduction until further movement is here, too, limited by pain. The shoulder is then abducted a little further and again held for a few moments. It is then slowly restored to the neutral position at the side and the patient rests until the pain subsides. Mild massage applied between movements will aid in easing the pain. These procedures are repeated several times depending upon the severity and duration of the affection.

Fig. 278 Fig. 279

Fig. 278.—Indian club exercise (the loop) for stiff shoulder.
Fig. 279.—Stretching of iliotibial band.

The patient then is treated in the sitting position. The above manipulation is repeated in this position, and the shoulder is rotated slowly in all planes (Figs. 275–277).

Finally the treatment is repeated with the patient standing. In this position internal rotation of the shoulder is carried to the greatest possible degree. This will frequently be the most difficult procedure, but it is very important. In order to strengthen the musculature of the shoulder girdle active exercises are finally added. Swinging of the arm in all directions, first without and later with the help of an Indian club will help to restore normal motion for the shoulder joint. (Fig. 278.) In all these manipulative procedures we cannot stress too strongly the need for care and consideration. The patient must be carefully observed and his endurance estimated. Loss of confidence will mean loss of the patient and almost inevitable stiffening of the shoulder, which may require operative intervention. Beneficial results must not be expected immediately, particularly in a case of long duration. Apparently hopeless conditions have responded in a satisfactory manner after treatment extending over periods of six weeks to even a year.

For the treatment of the lame back exercises are very important for the strengthening of the usually weak leg, gluteal, abdominal and back muscles. They are begun while the patient is still in bed as soon as the condition permits movement without causing too much muscle spasm. With the patient improving, more exercises are added until they can be continued with the patient in the standing position.

Fig. 280.—Stretching of calf muscles. Fig. 281.—Passive stretching of hamstrings.

Postural abnormalities should then be corrected. Bad posture very frequently is the source of low back trouble. Examination frequently reveals that many muscle groups controlling posture are in spasm or even contracted.

These muscles in question are the posterior muscle groups of the leg, calf and hamstring muscles, the tensor fasciæ latæ, the abdominals and the erector spinæ muscles. These muscles should first be stretched as shown in Figures 279–282.

Later on active exercises should be added in order to strengthen the gluteals by straight leg raising in the prone position. (Fig. 283.) Contraction of the abdominal muscles in the supine position should be given as shown in Figure 285 in order to strengthen their tone. Slow and rhythmical contraction must be obtained.

Physical exercises will help to re-establish proper coördination of the lower back muscles and will thereby decrease muscle spasm which very frequently is the cause for the continued pain. There again breathing exercises will play an important rôle in addition to exercises for the strengthening of the abdominal wall.

Contraindications.—Contraindications to exercises include, besides acute inflammations or active infections, any depleting disease or new growth.

In prescribing corrective exercises it is well to bear in mind that just as in other forms of physical treatments the best results are often obtained by combining several forms of treatments. Therefore a combination of exercises with heat and massage is often of great advantage and enhances the effect.

Fig. 282

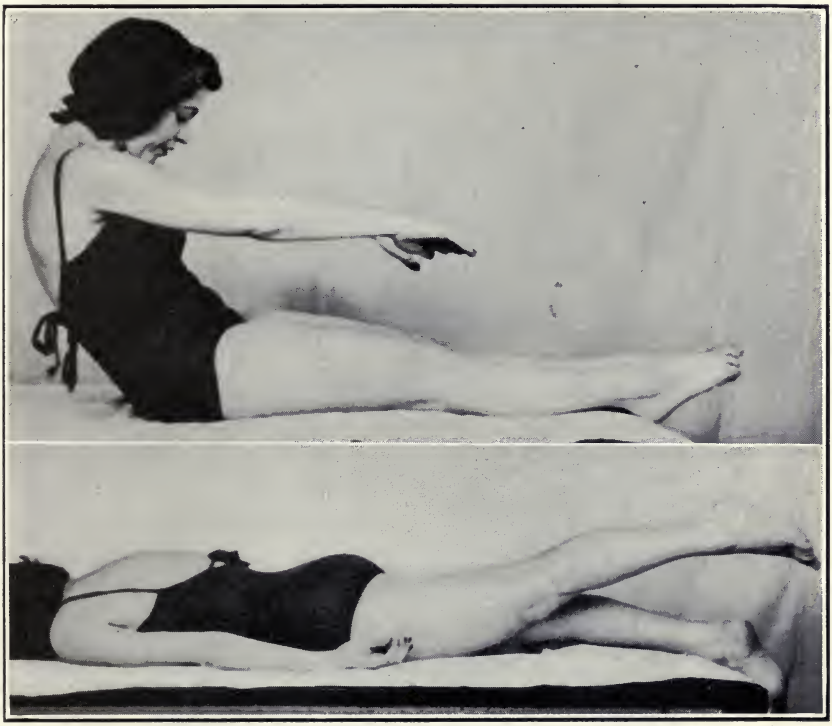

Fig. 283

Fig. 282.—Active stretching of hamstrings. This exercise also strengthens the abdominal muscles.

Fig. 283.—Strengthening of gluteus maximus by hyperextension of leg.

Posture.—Ewerhardt's definition of good posture is the mechanical correlation of various systems of the body with special reference to skeletal, muscular and visceral systems and their neurologic associations.

Proper posture is not inherent as is commonly supposed but is the result of constant thought, attention and discipline from earliest childhood. Its neglect makes for grave defects and consequent illness.

Improvement of faulty posture will improve many a condition caused by bad body mechanics and will result in better health. Figures 286 and 287 demonstrate faulty and corrected posture in the standing position.

Of perhaps greater importance than the treatment of deformities is their prevention. Examination of the very small child even below the age of two years will frequently reveal to the trained observer those slight or marked signs of muscle imbalance which might later lead to scoliosis if left uncorrected. A prominent scapula, a drooping shoulder, inequality of the extremities, habitual strained posture or imbalance of muscle tension form some of the outstanding points to be noted. Many deformities, however, have a definite and apparent cause. Some of these are congenital while many are hereditary. In many of these cases, for instance, in club foot or congenital hallux valgus, prophylactic therapy will naturally be of no avail.

Fig. 284

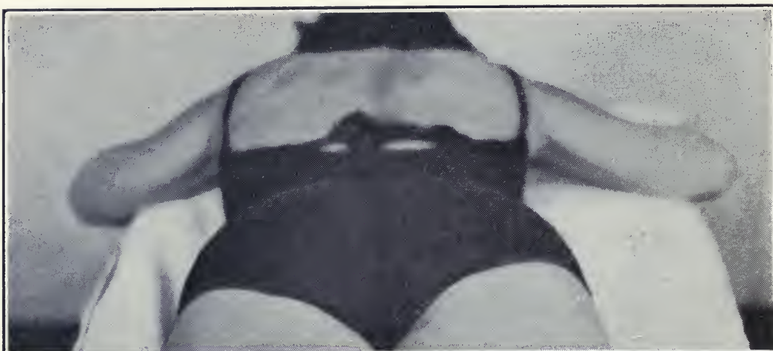

Fig. 285

Figs. 284 and 285.—Exercise of gluteal muscles. Fig. 284—relaxed. Fig. 285—contracted.

Many postural and other defects develop in older children, who in earlier years show no apparent abnormality. Since we cannot tell which child will grow straight and which one will develop postural defects it is the physician's duty, as supervisor of the rising generation, to make prophylactic exercises available to all children of school age and particularly of preschool age. Muscular education can be effected best during the early years of life, as it is during this period that the body still has the degree of flexibility which it is so desirable to preserve. Carefully supervised exercises will prevent the formation of habit errors in posture and carriage.

Habit errors and muscle imbalance resulting therefrom must be considered the cause of poor posture much rather than underdevelopment of the musculature due to chronic illness or to faulty nutrition.

Some of these exercises require apparatus while others do not. None is strenuous or exhausting. The exercises are given with the following principal objectives in view, namely to strengthen the muscles of the chest in order to benefit the circulation and respiration, to stretch the anterior shoulder girdle muscles which are frequently in spasm or shortened, to stimulate the abdominal muscles, and to stretch the shortened psoas group; to strengthen the muscles of the back and the weakened muscles

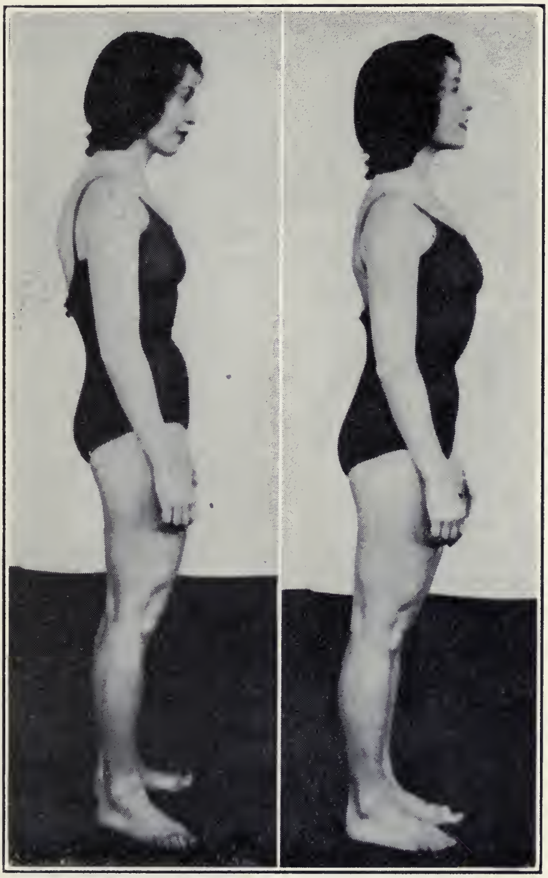

Fig. 286 Fig. 287

Fig. 286.—Bad posture: Head carried forward, chest sunken, round shoulders, abdomen sticking out, feet everted.

Fig. 287.—Good posture: Head up, chest raised, abdomen in, gluteals contracted, toes pointed straight ahead.

of the leg, especially the anterior tibials and the glutei, so that all muscle groups involved may secure the correct posture of the pelvis, the normal position of which is mainly responsible for good alignment of the entire skeleton. In this connection it must be mentioned that the posterior muscle groups of the legs, the calves and hamstring muscles very frequently show a tendency to shorten and to go into spasm. The cause for this spasm sometimes is obscure, sometimes it is due to diseases of the back or it is secondary to a weak foot condition. Wearing of exceptionally high heels may cause it or it may be the penalty we pay for standing in a position to which the human body is not yet fully adapted.

Tight posterior muscle groups may cause painful condition which could hardly be explained otherwise. Obscure pain in the lower extremities, the lower back, the shoulders, even the arms, can thus be explained and remedied by the application of special corrective exercises which will stretch the posterior muscle groups (Fig. 288).

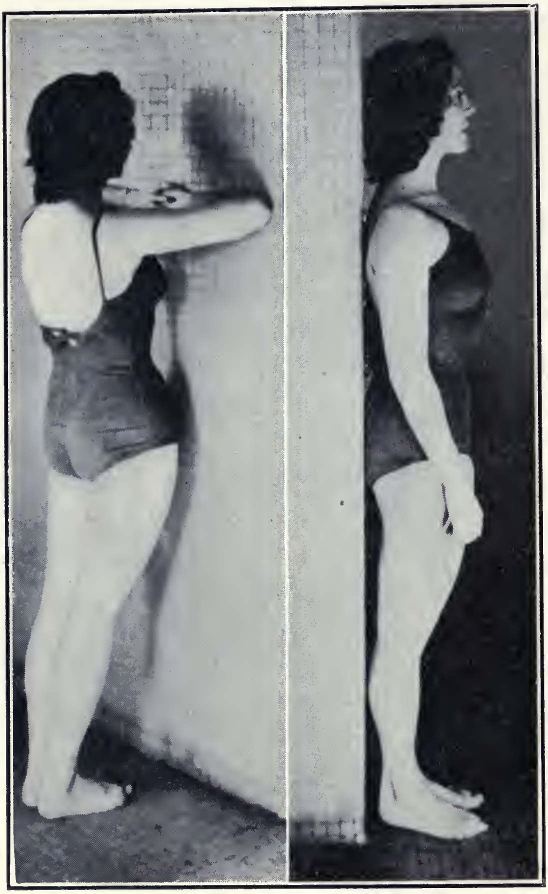

Fig. 288 Fig. 289

Fig. 288.—Exercise for stretching of posterior muscle groups.
Fig. 289.—Wall exercise to obtain proper posture.

Many methods have been described for promotion of proper posture.

Ewerhardt has suggested a useful posture test. By placing a proper distribution of weight on the feet and adjustment of hips, chest and head the patient raises his heels off the floor without further forward swaying of the body. The patient is instructed to repeat this test every hour for two to three weeks until he has learned "the feel" of this movement. Then repetition will establish the "habit" of the position.

In standing the patient must be reminded to assume the correct position of the pelvis. This is obtained by standing as tall as possible against the wall with back flat and abdomen in, the feet, hips and shoulders touching the wall (Fig. 289). This position must be maintained when walking. To avoid fatigue insist on frequent rests, lying and sitting, with proper respiratory exercises at regular intervals.

To secure proper poise without muscle tension the trunk should be in proper alignment with the weight forward and on the outer borders of the feet, the lower abdomen pulled in and up, the back flat, the chest raised, the head up, the chin in. The body must be stretched tall, easily without tension and the shoulders will assume their proper place. A firm flat abdomen is the foundation of good body mechanics; therefore, the abdominal muscles must be specially trained (Figs. 270–273).

Great attention must also be given to develop correct breathing as outlined above. If a patient shows too much fatigue, tension or weakness he should be kept in the recumbent position until he masters the entire muscle group.

The sitting posture likewise calls for the back flat against the back of the chair, the pelvis horizontal, the chest and head up, chin and abdomen in. Sitting as tall as possible without tension must be insisted upon.

Patients suffering from chronic diseases frequently fall into slovenly attitudes which will retard recovery and eventually lead to mental and physical defection. Bedridden patients unconsciously slump, especially when supported by a number of pillows. This is particularly true in traumatic cases and in arthritic and tuberculous conditions, and calls for constant vigilance. Poor body mechanics will then make for tension, fatigue and increased irritability.

The first consideration with a bed patient is to see that he is lying properly, that the back is flat, the chest up, the chin in and all muscles relaxed. This position must be maintained when the upper part of the bed is raised and pillows are placed for comfort. Stressing the raised chest and flat abdomen, and telling the patient to be tall will help to impress the lesson.

If postural exercises be instituted early and the position changed frequently, bedsores, wasting, constipation, weakness and prolonged convalescence can be avoided.

When a scoliosis has developed one should not assume that any group of back muscles can be isolated and strengthened by means of exercise as to correct a structural curvature. Such a technique would render the spine only more flexible and would therefore cause progression of the deformity. In functional scoliosis carefully chosen and supervised asymmetrical exercises may be of benefit to make the patient conscious of a lower shoulder or of a prominent hip. However, even there the use of symmetrical exercises is preferable. Experience has shown that children respond much better to this type of gymnastics.

Underwater Exercises.—In the re-education of a patient with muscle weakness corrective exercises in the gymnasium have proven to be of definite value. Two problems, however, present themselves when a patient is treated in the dry gymnasium, namely the elimination of gravity and of friction. The problem was met to some degree by various devices. Overhead swimming belts and slings to support the trunk and the extremities, smooth powdered boards to eliminate friction of the treatment table are helpful to a certain extent. Since it is known that a body will float in water despite its own weight a method was developed to utilize this medium for the treatment of weak muscles.

In water the action of gravity and friction can be eliminated. The body submersed into water loses weight because its specific gravity is so nearly that of water; therefore weak muscles are able to perform movements with greater ease, and even can execute action that could not be done in the dry gymnasium. In addition to this mechanical effect of the water its thermal effect also must be considered. Water of neutral temperature (92° to 96° F.) has a known sedative effect and will improve the circulation. Water of somewhat higher temperature (96° to 101° F.) will prove even more relaxing and will help in reducing muscle spasm. The sedative effect is of great importance in order to obtain a smooth rhythmic coördinated movement.

Two means of underwater exercises have been developed, the large pool with its moderate temperature and the tank, the temperature of which can be adapted more readily to the individual patient's needs.

Tanks of various shapes have been devised to permit as complete a range of motion of the extremities as possible. The key-hole shaped Hubbard tank is widely used, as is the butterfly shaped Currence modification (Fig. 250). These tanks are constructed of monel metal which renders them durable and non-corrosive. But even a galvanized iron tank usually used for different purposes and available through mail order houses could be adapted for underwater therapy.

The patient is lowered into the tank by means of an overhead trolley. In the tank he is supported by a shoulder sling or a plinth depending on how much support is required. The temperature of the tank ranges between 96° and 101° F. The average duration of the treatment is twenty minutes. The exercises are given by the technician standing outside of the tank. They may consist of passive or active exercises. Whirlpool agitators can be placed in the tank for an added hydromechanical effect (Fig. 251.) This will stimulate the skin, improve the circulation and will have a toning effect.

The tank lends itself for treatment of a great variety of conditions. It is largely used for patients suffering from rheumatic and arthritic disorders, also for mobilization of limbs following fractures and postoperative orthopedic procedures. As a general rule to acquaint patients with underwater therapy the tank is used before the institution of pool therapy. This will eliminate apprehension and fear of water.

The therapeutic pool should be located in a light and well ventilated room. It should be sufficiently large to accommodate two to four patients and one or two technicians. It should be about 24 to 26 feet long, 12 to 15 feet wide, the depth should be graded from 2 to 4 feet. The floor should consist of non-skid tile. Underwater lights are an excellent addition. There should be an overflow gutter, strongly built so that appliances and supporting rests may be hung from it and also to enable the patient to hold on for free exercises. The temperature of the water should be 90° to 94°, the room temperature about 86° F. The water must be filtered and sterilized and preferably constantly circulating. Sterilization is effected by chlorination or by means of ultraviolet light. The chlorine content of the water is checked several times a day with the Hellige colorimetric method. Bacteriological tests for B. coli are taken twice a week. Suction cleaners are used twice a week and the pool is emptied and scrubbed once a week or once in two weeks depending on its use and load.

Before the patient in his bathing suit is lowered into the pool by means of a stretcher on a ramp or by an overhead trolley he is asked to void and then given a cleansing shower. In the pool he is floated by the technician to his particular station either to a monel metal plinth or to a trunk or head support. The various types of supports are necessary to localize as much as possible muscle action and to prevent muscle substitution. Splints may be applied to keep an extremity supported.

The technician can give exercises to one patient while supervising another in the pool. One technician should not attend to more than 2 patients at a time unless she is teaching swimming to a homogenous group.

The average treatment will last up to thirty minutes, after which time the patient is removed from the pool, dried and moved to an adjoining solarium or rest room.

Pool treatments were originally introduced for the redevelopment of muscles weakened by infantile paralysis. Even in the acute phase of the disease hot pool treatments have been recommended by Hipps and Crook and long previously by others. Today the scope of the therapeutic pool has been widened. Postoperative orthopedic conditions, sciatica, low back pains, osteo- and rheumatoid arthritis, spastic paralysis, muscular incoördination and various neurological conditions have been benefited by the underwater therapy. Experience has shown that the low back syndrome group has done unusually well in the pool. Since movement is much easier under water, the danger of increasing spasm in the back muscles is decreased.

The psychological effect of comparatively easy movement of the patient must not be overlooked.

Most patients prefer pool and tank treatments to dry gymnasium treatment because of the obvious relaxation and ease of movement experienced in the pool.

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PART V

Applied Physical Therapy

CHAPTER XXIV

CARDIOVASCULAR CONDITIONS

General Considerations. Review of Physical Measures. Angina Pectoris. Hypertension. Exercise in Cardiac Patients. Hypotension. Cardiac Neuroses. Peripheral Vascular Disease. Diagnostic Considerations. Review of Physical Measures. Neurovascular Disorders. Raynaud's Disease. Organic Vascular Disorders. Arteriosclerosis Obliterans. Thromboangiitis Obliterans. Thrombophlebitis. Acute Thrombosis and Embolism. Care of Feet in Peripheral Vascular Disease.

General Considerations.—Physical measures in the treatment of internal medical conditions form an important part of their routine management. The European literature has contained for many years studies by clinicians of physical therapy in medical conditions and it is a sign of definite progress that there appear now in the American literature on the same subject, an increasing number of contributions on controlled clinical and experimental studies. These measures will be of best service in the hands of a good clinician, who employs them in conjunction with other indicated therapeutic measures and not to their exclusion. Their rational employment must be based on a definite diagnosis and a clear conception of their physiological effects, and of course, also on a safe and efficient technique of application.

All competent clinicians agree that there is a large field of applicability for physical therapy in cardiovascular disorders. Rest, voluntary exercise, massage and mechanotherapy, hydrotherapy and electrotherapy may be employed, according to the type and stage of the disorder and the circumstances of the patient. Physical measures are especially valuable in cardiovascular psychoneuroses or the nervous type of cardiac diseases; but even in hypertension or arteriosclerotic cardiovascular disease or that caused by other general systemic degenerative diseases—syphilis, bacterial infections or toxins—much relief can be given by properly selected and applied physical therapeutic agents. Many of these measures can be effectively applied at physicians' offices and the patients' home; others involve institutional care or belong to well-equipped health resorts.

Review of Physical Measures in Cardiac Conditions.—**Rest and Relaxation.**—Physical as well as mental rest is a primary measure of effective treatment in all cases of circulatory insufficiency and in many cases of nervous heart conditions. Reduction of activity in less severe cases requires judgment and experience. It has been shown that excessive neuromuscular tension tends to maintain elevated blood-pressure even in normal individuals, while cultivated relaxation of skeletal muscles (Jacobson) has enabled a satisfactory control of many cases of hypertension. Undoubtedly part of the favorable effect of many physical therapeutic office procedures can be traced to their systematic introduction of a period of rest and, at least, partial relaxation amidst an active daily life.

Exercise.—Active exercises if performed gently, slowly, evenly and with sufficient rest between movements, aid more than stimulate the heart in its work, provided cardiac insufficiency is not too pronounced. They stimulate respiratory movements and thus facilitate pulmonary circulation. Vigorous exercises enhance the work of the heart and with enough cardiac reserve power present, a grading of exercises can be accomplished according to the individual cardiac condition.

Massage and Passive Exercise.—When the patient is confined to bed because there is marked dyspnea even during rest and the heart is unable to maintain a fairly normal circulation, gentle stroking massage and passive movements may be instituted. Massage tends to move the blood out of the veins of the manipulated parts, while passive movements cause an alternate lengthening and shortening of blood-vessels and expression of the blood towards the heart. Most of these patients also respond well to general body massage. Gentle electrical muscular exercises of the extremities by the Bergonie method or by other surging low frequency current applied in a water bath are also of definite clinical value.

Hydrotherapy.—A cold bath at 85° F. and less increases peripheral resistance and thus slows the heart's action and increases its work. Warm baths, 100° to 104° F., increase the heart frequency and lower the blood-pressure by decreasing the peripheral resistance; arterial tone falls, and despite the increased work of the heart, the needed increase of blood flow to the heart muscle may not take place. Such baths are therefore contraindicated in coronary sclerosis.

In the carbon dioxide bath the tiny bubbles of the gas stimulate the nerve endings and give rise to the sensation of heat. In addition, the fine bubbles of carbon dioxide covering the body prevent heat loss; hence a bath containing carbon dioxide can be given at a decidedly lower temperature than one without it. These baths cause dilatation of the peripheral vessels, and increase pulse-pressure, the cardiac output, and the blood-pressure. At 92° F. they facilitate the work of the heart, while at lower temperatures, about 86°, they stimulate its action.

Electrotherapy.—Electrotherapy is chiefly employed in the form of cardiac diathermy, although some clinicians have reported results with mild galvanic treatment through the cardiac area. Deep heating of the cardiac muscle and its blood-vessels should increase the blood flow to an impoverished myocardium and causes disappearance of the partial anoxemia.

A small heat lamp applied to the cardiac area for fifteen minutes to half hour, will often give relief in cases of precordial distress due to neurosis or reflex irritation; in others, short applications of the Oudin current may be helpful.

Angina Pectoris.—There are no definite pathological changes responsible for this distressing symptom complex, consisting of recurrent attacks of severe pain in the region of the heart radiating to the shoulder and often accompanied by great anxiety and fear of approaching death. Some cases show alterations in the aorta, and changes limited to the muscles of the coronary arteries. In patients beyond middle age there may be general arteriosclerotic changes. In younger individuals, aortitis, primarily luetic, may be the underlying cause. During the acute attack, physical measures of treatment consist of absolute rest and mild heating to the precordial region.

Recent studies by Freedberg *et al.*[6] on the effect of external heat and cold on patients with angina pectoris support the concept that coronary artery vasomotor changes, probably reflex in origin, exert a contributory influence in precipitation of attacks of angina pectoris and that heat acts as a coronary vasodilator and cold as a vasoconstrictor, or to prevent vasodilatation. Prophylactic use of heat enables many patients to do considerably more work in a cold atmosphere and suggests that local application of heat may be valuable in preventing attacks in daily life under certain circumstances.

Cardiac diathermy has been reported on favorably by Hyman[7] and by observers abroad as an interval treatment of angina pectoris caused by coronary disease. Either form of diathermy may be employed: one condenser pad or metal electrode corresponding with the size of the heart is placed over the cardiac area and a somewhat larger dispersive electrode over the back. A single coil or treatment drum may also be employed. A very moderate strength of current, 500 to 750 milliamperes with long-wave diathermy, is employed for ten to twenty minutes. The patient is best treated in the sitting position and a careful check on the rate and quality of the pulse must be kept and, after treatment, he should rest in the recumbent position for one-half hour before he is allowed to leave the office. Whenever so indicated, home treatment may be administered with a portable machine at the patient's residence.

In the majority of Hyman's cases with coronary thrombosis and with electrocardiograms showing deviations of the terminal ventricular complex, diathermy gave symptomatic relief in those instances when standard methods of drug therapy had failed to produce any lasting benefit. Simultaneously with the clinical improvement there was improvement in the electrocardiograms, the previous negativity of the T-waves first lessened and then a normal positive deflection was obtained. These cases were all treated at least six months or later after their last attack. Hyman is of the opinion that diathermy will do more harm than good in the acute and subacute stages of coronary disease.

The dramatic results reported by Nagelschmidt[12] with diathermy in acute attacks of angina pectoris may possibly be explained by the fact that these cases were mostly attacks of pseudoangina, caused by a cardiac neurosis. In such event, diathermy may bring immediate relief.

Hypertension.—The level of the blood-pressure is a resultant of several factors, chiefly the cardiac contractions, the arterial recoil, the arteriolar peripheral resistance and the state of the capillary bed. Continued high blood-pressure occurs from a number of different causes: (1) nephritic conditions, such as acute glomerulonephritis; (2) essential hypertension and (3) symptomatic hypertension due to hyperthyroidism, denervation of the carotid sinus, etc. Essential hypertension is still idiopathic as to its origin. According to some, it represents the first stage of arteriosclerotic high blood-pressure, while according to others, it is brought about by toxic, nervous or other factors, causing an increased tonus or spasm of the arterial walls. There seem to be no demonstrable anatomical changes, only functional disturbances in this primary type. In the other types of hypertension there are pathological alterations in both small and large blood-vessels, arteriosclerosis, aortic insufficiency and degenerative processes in the kidneys and brain. These changes result in increased heart action and a permanent increase of blood-pressure and, as this is necessarily a compensatory measure, there is usually no justification for physical therapy directed toward a lowered pressure. We do not combat fever as a symptom unless its continued intensity endangers the organism.

Physical measures are of a recognized value in the essential type of hypertension. It is a well-known fact that increase or decrease of blood-pressure can be induced by a number of physical agents. Rest, avoidance of bodily and mental exertion is the simplest and most rational of these. Others are the high-frequency current, carbon dioxide baths, general ultraviolet irradiations and hot body baths. Not every case of primary hypertension needs treatment, only those in which there appear such definite symptoms as headache, dizziness and a sense of oppression.

Several methods of high frequency application, local and general, have been reported on favorably in the reduction of essential hypertension. The earliest ones were autocondensation and general diathermy, advocated by Albutt and others. The technique of these two methods is described in Chapter XI. The physiological effects are chiefly attributable to the mild general heating action, consisting of flushing and capillary dilatation; mild sweating may occur, while metabolism is quickened with an increase of solids in the urine. These effects are coupled with a relaxation of the vascular periphery, leading to a fall in blood-pressure. The fall as a whole is usually temporary but, over a series of treatments, as a rule a small net gain results. The symptomatic improvement is usually marked and may be explained by a redistribution of the vascular load, a tonic effect on the heart muscle and the metabolic stimulus following the repeated mild general heating and relaxation. It appears as if a vicious circle is being interrupted and the normal tendency to correction is allowed to exert its influence. Treatments should be administered on alternate days at first; after about a dozen treatments, depending upon the result achieved, the frequency of treatments is gradually reduced. If in patients with a primary hypertension there is no reduction after a course of treatment, the existence of marked organic changes may be suspected.

Clinical work with short-wave diathermy has established several new techniques of treating essential hypertension. Laubry, Walser and Meyer[10] report that transcerebral short-wave diathermy of weak intensity but of comparatively longer application ordinarily reduces the tension by several degrees. Comparatively good results were obtained by intense heating with short-wave or long-wave diathermy of the muscular masses of the extremities. Reduction of pressure was noted irrespective of the localization of short-wave or diathermic application. Intense dosage has permanently lowered the arterial tension in some patients. Types were encountered in which no measure produced a reduction of pressure, while in others, any form of treatment resulted in reduction, but this effect was difficult to maintain. These clinicians are of the opinion that the manner in which either local or general short-wave applications affect angina pectoris and high blood-pressure is not definitely established. Undoubtedly, there is an underlying effect on the sympathetic nervous system which apparently reacts more favorably to low intensities of local short-wave irradiation; however, that the thermic effects play an important rôle need not be doubted.

The view that the factors inducing lowering of essential hypertension are sympathetic reflexes, is supported by the results reported by Pizarro and Levisman[14] following application of diathermy to the carotid sinuses. They selected patients who did not improve on rest and applied diathermy by two electrodes of 1 by 3 inches over the carotid sinuses of the neck and a dispersive electrode of 4 square inches over the pectoral region. This treatment lasted ten minutes and its duration was increased five minutes every other day up to thirty minutes.

Short-wave diathermy to the kidneys in cases of hypertension due to nephrosclerosis has been recommended by Rausch.[15] Patients are treated in the recumbent position with condenser pad electrodes of equal size over the kidneys and the abdomen and a felt spacing of 1 to 2 cm. between the electrodes and the body. Treatments of one and one-half to two hours' duration, at heat of comfortable toleration are applied. Best results were seen in cases where the sclerosis was in its initial stage and no changes in the renal parenchyma have taken place. Trolow[21] and associates report on long-wave diathermy to the iliac plexus and the suprarenals in hypertension and attribute the favorable result to an effect on the endocrine-sympathetic system and an amelioration of the vascular spasm in the abdominal organs. Two electrodes of suitable size were placed so as to cover the two kidneys and the suprarenals and a third electrode was applied in the center of the epigastrium. A current from 500 to 2000 MA was applied for five to ten minutes and the patient had to rest thirty minutes afterwards. Out of 25 patients blood-pressure was reduced in 15 and this lasted from eight to ten months in some of the cases.

Among other physical measures for relief of arteriosclerotic cardiovascular disease is the galvanic bath, administered as a full bath or a four cell bath (Chapter VIII). It has been recommended in compensated valvular lesions for the increase of the reserve strength of the heart and also in selected cases of myocardial weakness and cardiac neuroses for general tonic effects, similar to those of the carbon dioxide (Nauheim) bath. These and some other measures are often best administered under close supervision in well-equipped health resorts or institutions.

Exercise in Cardiac Patients.—Exercise is one of the most important measures in patients with ambulatory cardiac conditions, arteriosclerotic and other. Nylin[13] states that no standard program for exercises can be given, but the following rules must be strictly observed: (1) There should be an interval of at least one hour between a meal and the exercises. (2) No exercises should be taken in the evening. (3) Treatment must be progressive. (4) In the beginning, exercises are taken in the supine position, later in the sitting and then the standing position. (5) The force of gravity must be considered in execution of the exercises. The operator may have to assist movement in upward raising of the leg or trunk and may have to resist it in lowering the part to the horizontal position. (6) Uni- or bilaterality of exercises of the extremities and their range must depend on the amount of cardiac reserve power. (7) An individual exercise is not repeated in the same part of the body, but the whole set of movements may be repeated if the patient's condition permits. (8) Inspiration must accompany exercises of the arm that expand the thorax, expiration those that compress it. (9) A pause of two or three minutes should follow each individual exercise. (10) Five to 10 deep respirations should precede and follow each whole set of exercises.

The Stokes-Oertel method of terrain exercises practiced in health resorts, consists of graded walking outdoors, first on level ground and for a short distance; as cardiac function improves the distance is gradually lengthened and the walking done on a gradually inclined plane. The pace should be slow and even with frequent periods of rest. If dyspnea occurs, walking is discontinued until breathing has become normal. Benches and markers are placed at intervals along the path, and a competent attendant accompanies the patient, or a conveyance is held ready to take the patient home if he becomes tired.

Hypotension.—The etiology of "essential" low blood-pressure is as idiopathic as that of essential high blood-pressure. Its syndrome includes fatigue, lack of physical and psychological tone, pallor and depression. Although any cardiac abnormality may not be present, signs of circulatory insufficiency abound, such as irregular pulse, acrocyanosis, limpness of skin and muscles. Low blood-pressure can be raised by peripheral stimulants which reflexly affect the endocrines or the autonomic nervous system. The static modalities are foremost among these, such as the static head breeze, static insulation and the static wave current applied to the spine. The Oudin current through a condenser electrode played up and down the spine or over the abdomen exerts a similar effect. Short applications of diathermy directly to the heart also raise the blood-pressure by improving the tone of the heart muscle. General ultraviolet irradiations are also useful.

A course of thermal baths is often helpful: they must be of short duration at first, and then gradually lengthened. Additional general massage or exercise are valuable if carefully administered.

Cardiac Neuroses.—A very large group of patients with temperamental, unstable make-up complain of pain which, they believe, originates in the heart. At times patients with an organic heart disease present exaggeration of symptoms which are clearly psychogenic. Palpitation, dizziness, shortness of breath are the most common symptoms complained of in those patients. Profound emotional disturbances, a misinterpreted remark of an examining physician, or a series of dramatic exertions like in the late war, are the precipitating factors.

Physical therapeutic procedures are eminently suitable to combat these cases, for they render not only subjective comfort but also allow repeated reassurance on the physician's part, the restoration of the patient's confidence; one should choose between thermal, hydriatic and electrical measures the most suited for the patient's condition: a simple heat lamp, cardiac diathermy or galvanic current in mild cases for combating pain and palpitation, general ultraviolet irradiation in increasing doses, hydrotherapy in the form of Scotch douche, general body massage for tonic and sedative purposes. At times the removal from home environment, and treatment in a resort or institution equipped with all physical therapy modalities may be advisable.

PERIPHERAL VASCULAR DISEASE

The study and treatment of peripheral vascular disease has made considerable advance in recent years and physical measures play a definite rôle in its treatment. The common feature in all types of the disease is an obstruction of the peripheral vascular bed and there are two main factors in this condition, vascular spasm or organic occlusion.

TABLE 51.—CLASSIFICATION OF PERIPHERAL VASCULAR DISEASE (DE TAKÁTS)[20]

Organic	*Functional*
Acute	Vasospastic
Thrombosis	Neurogenic
Embolism	Mechanical
Chronic	Endocrine
Anomalies	Toxic
(1) Congenital	Vasoparalytic
Occlusions	Erythromelalgia
(1) Traumatic	
(2) Inflammatory (thrombo-angiitis)	
(3) Degenerative (arteriosclerosis)	

Diagnostic Considerations.—In treating peripheral vascular disease the first prerequisite is a definite diagnosis. Unrecognized cases of this condition are often treated under such stereotyped diagnoses as neuritis, flat foot, varicose veins, periostitis and myositis. The next prerequisite is a differentiation of the type and extent of the vascular occlusion including the determination of how much dilatation the vascular bed is capable.

The simplest tests are the palpation of the arteries of the lower extremity, the femoral, popliteal, dorsalis pedis (first interosseal space) and the posterior tibial (behind internal malleolus). Occasional instances of absence of pedal pulses in case of existing adequate circulation can be discounted by the good color and warmth of the feet. In spastic occlusion, at times, the presence of pulsation may vary. Color changes with the elevation of the leg are also valuable signs but the most useful ones are those of determining the skin temperature of the extremities. Differences between two sides greater than about 1° F. are discernible by the palpating fingers or the palm of the hand. Electrical readings of the surface temperature of the skin with thermocouples are now available for accurate measuring.

Oscillometric examination by the readings of a delicate pressure recording device, the oscillometer, records the extent of the arterial blood flow in the extremities. Comparison of the pressure levels of two sides known as the oscillometric index, may furnish evidence of unilateral peripheral vascular disease, or comparison with normals may furnish evidence of bilateral general vascular disease, if both indices are equally decreased. In the presence of major arterial obliteration the oscillometric reading is very low; in spastic conditions of major arteries it is somewhat lowered, while in purely arteriolar obliteration or spasm it is practically normal.

According to de Takáts[19] patients with organic arterial disease are divided into four groups: (1) those who have an oscillometric index of over 0.5 cm. at the ankle, who complain of claudication after walking five blocks or more and who have no pain at rest; (2) those with an oscillometric index under 0.5 cm., who complain of claudication within two blocks and who have no pain at rest; (3) those who have continuous pain at rest, show no or minimal oscillations at the ankle and have signs and symptoms of ischemic neuritis; (4) those who have actual gangrene with no oscillations at the ankle. Obviously there are borderline cases, as there may be some variation of these criteria from day to day.

Landis and Gibbon[9] use an easily applicable diagnostic test to determine how much dilatation of the vascular bed is possible. The patient is placed in a recumbent position in a room at temperature of about 70° to 72° F. The temperature of the skin surface of the big toe is determined with an ordinary fever thermometer. The arms and hands of the patient are then immersed in hot water at about 113° F. for twenty minutes; this causes a reflex vasodilatation and now a second reading on the big toe is made. If a normal reading of 91.4° F. is obtained, it shows that either there is sufficient vascular bed to overcome the organic obstruction or there is an element of spasm present. If the normal vasodilatation level of 91.4° F. is not reached, there must be a deficiency of available collateral circulation and a diminution of safety factors. This will frequently occur in arteriosclerosis, thrombo-angiitis obliterans and embolism.

Review of Physical Measures in Peripheral Vascular Disease.—A somewhat bewildering variety of physical measures, thermal, mechanical, electrochemical has been proposed in the treatment of peripheral vascular diseases. Every method and apparatus has its merit in the proper place, but none should be applied indiscriminately, because it may produce more harm than benefit. The skin and underlying tissues of an extremity suffering from peripheral vascular diseases are very easily vulnerable by mechanical, chemical or thermal agents. Therapeutic measures which in usual conditions would not damage tissues are apt to produce gangrene and necrosis in ischemic extremities which in turn may necessitate major amputation. Barker[1] reported that the precipitating cause of ulceration and gangrene in approximately 39 per cent of a series of 171 cases of thrombo-angiitis obliterans and in 35 per cent of 115 cases of arteriosclerosis obliterans was due to ill-advised therapeutic procedures.

In order to avoid repetition, the pertinent physiological and clinical effects as well as the contraindications and dangers of the numerous physical therapeutic measures will be first presented in detail, while the pathological considerations and the scheme of treatment of each condition will be discussed subsequently.

Thermal Measures.—Heating causes an increase of circulation and metabolism which is paralleled with the increase of temperature; but while heat increases considerably the rate of blood flow in a normal extremity, in peripheral vascular diseases, where the circulation is impeded as a result of organic or spastic changes, little or no increase of blood flow may be brought about. The consequence is that the excess amount of heat which in normal conditions would be dissipated by the increased circulation, remains locally concentrated in the tissues and, therefore, easily results in severe burns and gangrene of the extremities. Therefore, in all forms of thermal applications the vulnerability of tissues with poor blood supply must be remembered and it should become axiomatic, that the more the circulation of the limb is interfered with, the nearer the neutral point must be the temperature of application. (Scupham.[16])

Generally speaking in all cases of peripheral vascular disease circulation of the extremities should be increased by warming the patient's trunk and thighs or opposite normal extremities (reflex action) or by a generally increased blood flow. Conductive heating from hot water bottles and electric pads should not be applied directly to the extremities.

Thermostatically controlled heating, according to Starr and Bierman, is the safest form of heating. A heating hood, as illustrated, is placed over the affected parts and the temperature control is adjusted between 93.2° and 95° F., at the degree at which it gives the greatest comfort experienced by the patient; the constant maintenance of such a temperature keeps the circulation nearest to normal. In case of gangrene and ulceration, controlled heating may be kept up for twenty-four hours. In emergencies and the absence of thermostatic control, an ordinary heating cradle can be standardized to maintain a given temperature by means of light bulbs of graduated wattage; the patient may be instructed to turn on or off as many lights as will give him most comfort.

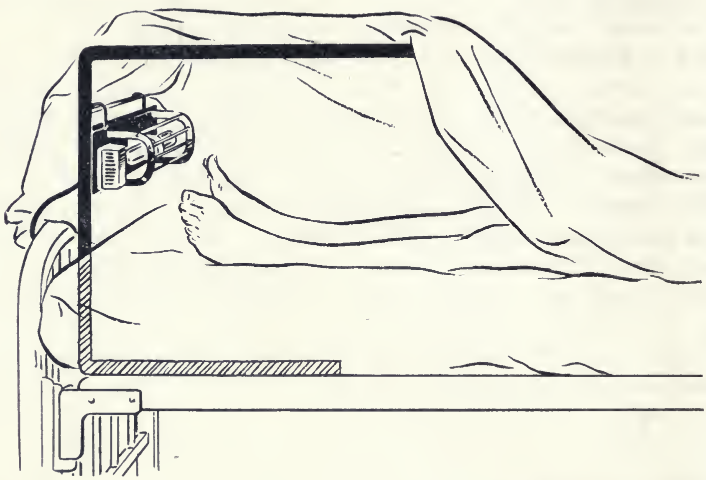

FIG. 290.—Diagrammatic view of arrangement for constant temperature treatment of lower extremities. (Courtesy of Ille Electric Corp.)

Hot soaks may be employed in the treatment of gangrene and ulcers, especially to remove thick sloughs and crusts, but the temperature should never be more than 102° to 105° F. Strong antiseptic solutions should never be used; boric acid is the most commonly used substance. In the treatment of acute thrombophlebitis hot wet packs may be used.

Hot baths if employed should be of increasing temperature, starting at 95° F. and slowly increased to a comfortable temperature, but never over 105° F. Behrend[3] advocates the use of partial baths of slowly increasing temperature in obliterative vascular diseases. The temperature is slowly raised within fifteen to twenty minutes from 37° C. to 44° C. Duration of the bath is fifteen to forty-five minutes. Slowly increasing temperature dilates the capillaries, and the plethysmographic studies proved that the deeper located arteries are also dilated.

Contrast baths have been widely advocated as a home treatment for peripheral vascular disease, especially for the symptom of intermittent claudication and in frostbite. Their technique has been described in Chapter XX. Contrast baths act as powerful skin stimulants, but do not increase collateral skin circulation. They can be employed twice a day;

care must be taken that the feet are carefully dried afterwards to prevent cracking or maceration.

Diathermy is capable of inducing dangerous amounts of heating when applied to extremities with vascular disease. Even with the most expert technique there may occur increasing pain, cyanosis or, at times, definite pallor by reflex ischemia. It is now generally recommended that diathermy never be applied to the area of involvement, but higher up, to the thigh, lumbar region, or the trunk, so as to cause increased circulation indirectly without local overheating. The method of electromagnetic field heating is especially convenient, with the inductance coil wound round the thighs or the lower abdomen.

Hypothermy has been recently recommended in the prevention and treatment of gangrene resulting from arterial occlusion and will be discussed further under arteriosclerosis obliterans.

Electrochemical Measures.—Ion transfer with vasodilating drugs is being employed on an increasing scale in treatment of certain types of peripheral vascular disease, with the technique described in Chapter VIII. Very satisfactory results have been reported by J. Kovács,[8] Montgomery *et al.*[11] in Raynaud's disease and scleroderma; painful ulcerations in some of these cases also healed concurrently.

Chronic ulcers associated either with varicose veins or with occlusions following phlebitis seem to respond very well to this treatment; encouraging results have been seen in both acute and chronic phlebitis.

Mecholyl ion transfer is contraindicated in patients who show constant elevation of temperature, also in cases complicated by asthma. Caution must be exercised and shorter treatments given to patients with heart involvement and to old persons in a feeble condition.

Histamine ion transfer may be employed for the same indications but the therapeutic results have been less satisfactory.

Mechanical Measures.—*Rest* in bed with the extremities in horizontal position—is of the utmost importance in all types of obliterative vascular diseases where gangrene or ulceration is present. It is also essential in acute embolism or thrombosis. To achieve full benefits it is necessary to find the level of greatest circulatory efficiency—which is usually from 10° to 15° below the horizontal level.

Postural exercises, first recommended by Buerger, are most valuable in the early stage of obliterative vascular diseases. It has not been proven that such exercise promotes the development of collateral circulation, but by emptying the vessels of old blood and filling them with new it seems to increase the peripheral circulation and promote tissue nutrition. The exercises are effective only if they are carried out systematically over a long period of time. The technique of Buerger's classic exercises is very simple: The patient should start the exercises lying horizontal in the bed. (1) The legs are elevated to 45 degrees for one-half to two minutes, depending on the length of time for complete blanching of the feet to occur. (2) Immediately after the first exercises the patient sits on the edge of the bed with his legs dependent, for two to three minutes, to develop an actual redness of the feet. (3) He completes the cycle by lying in a horizontal position for three minutes. Usually five cycles are done consecutively and the exercises are carried out two to three times daily. Intermittent claudication seems to be the most benefited. In gangrene or ulceration this form of treatment is contraindicated.

Intermittent venous occlusion produced by an inflatable cuff, brings about an increased blood flow by an active dilatation of the arterioles of the compressed extremity. This method is fairly simple and inexpensive, and

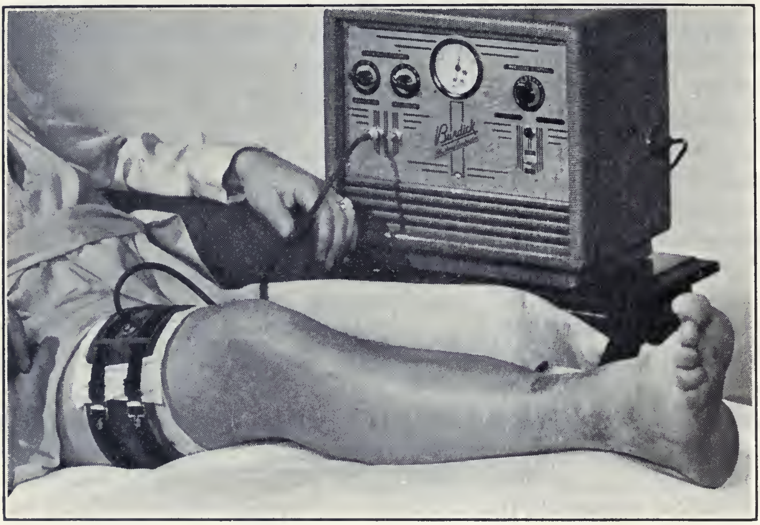

Fig. 291.—Rhythmic constrictor. (Courtesy of The Burdick Corp.)

its chief advantage is that it can be carried on for months away from the hospital: one leg can be treated in the morning, the other in the afternoon. de Takáts[20] states that in acute occlusions and threatening gangrene, which require several hours of treatment, suction and pressure therapy

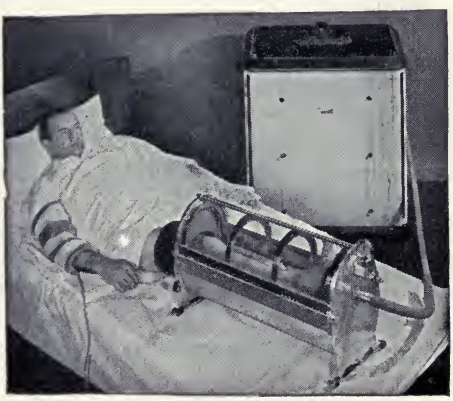

Fig. 292.—Suction-pressure unit. (Courtesy of The Burdick Corp.)

is more preferable, while in ambulatory patients, especially those living far from hospitals or who cannot afford a long series of treatments, the inflatable cuff therapy is preferable. This is also given to patients who have undergone sympathectomy for Buerger's disease or who have had one leg amputated and the other leg is showing the first or second stage of vascular occlusion.

Passive vascular exercise (pavaex) is based on the observation by Landis[9] and others that by employing environmental changes in pressure periodically to the surface of a limb, there is an increased blood flow and some elevation of skin temperature. At least temporary relief of "rest pain" and healing of indolent ulcers are also observed. From a review of the therapeutic results nothing has pointed to a permanent improvement following the temporary benefit of the treatment. The uniform opinion is that thrombo-angiitis obliterans does not respond so well to this form of treatment, and other simpler methods often produce better results. This is especially true in cases with intense rest pains or if an acute migratory phlebitis is present. On the other hand in acute arterial occlusions, frostbite and arteriosclerosis obliterans with or without diabetes, passive vascular exercises have been proved of value. Especially the latter group of patients often do not tolerate other forms of treatment. It is contraindicated if any acute or subacute inflammation, cellulitis, lymphangitis or thrombophlebitis is present. It should be particularly avoided in the purulent type of diabetic gangrene.

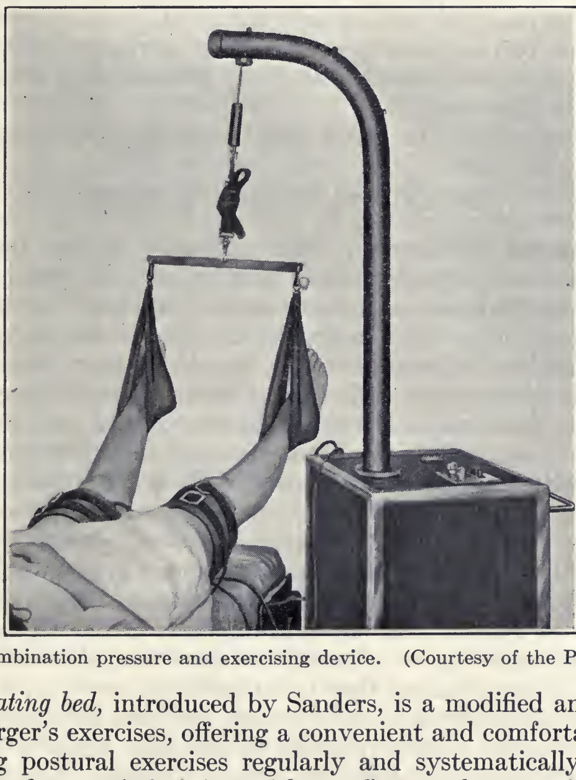

FIG. 293.—Combination pressure and exercising device. (Courtesy of the Plethorator Co.

The *oscillating bed*, introduced by Sanders, is a modified and improved form of Buerger's exercises, offering a convenient and comfortable method of producing postural exercises regularly and systematically as well as passively for a long period of time without effort on the part of the patient. The unit is, in principle, a motorized hospital bed in which the head and the foot is alternately elevated and lowered. It can be applied for several hours daily without any discomfort. The speed of the cycle can be adjusted. It is indicated in the obliterative form of vascular diseases.

Combinations of the oscillating bed and venous hyperæmia have been recently introduced. The unit shown in Figure 293 elevates the extremity by means of a sling and cuff at a rate of fifteen times an hour; it also inflates the cuff at regular intervals up to the level of diastolic pressure, followed by automatic deflation. These procedures can be employed combined or separately and thus the apparatus is applicable in obliterative as well as in traumatic vascular deficiencies.

NEUROVASCULAR DISORDERS

Raynaud's Disease.—The typical signs are attacks of vasomotor spasm, extreme pallor of a sharply circumscribed area, numbness and severe pain along the symmetrically affected extremities, more frequently the upper ones. The cause of this condition is still unknown, but is probably central; local cold as well as anxiety or anger, may bring about or exaggerate attacks. Vasoconstriction of this nature may be relieved by peripheral stimuli; a failure to respond by dilatation is a sign of organic lesion.

The most effective palliative measure in Raynaud's syndrome is iontophoresis with vasodilating drugs, mecholyl or histamine, with the technique described in Chapter VIII. This treatment is especially valuable for the relief of pain and the healing of ulcers. A systematic course of 10 to 20 treatments two or three times a week is advisable. Mild degrees of heating and, in selected cases, ultraviolet irradiation in mild sunburning doses, may be also considered.

In *scleroderma* similar measures as in Raynaud's syndrome are useful.

ORGANIC VASCULAR DISORDERS

Arteriosclerosis Obliterans.—Arteriosclerosis is the most frequent organic peripheral vascular disease; it is primarily a senile degenerative process in both the intima and media and is particularly common in males after the age of fifty. Arteriosclerotic changes are also underlying in the diabetic vascular disturbance, which usually appears about ten years earlier and is characterized rather by occlusion of smaller vessels. In most cases of arteriosclerosis the typical pipe-stem radials and the prominent and tortuous temporals are visible evidence of the widespread location of the degenerative changes. The arteries of the lower extremities are much more frequently affected, however, than those of the upper extremities.

According to de Takáts[19] so long as myocardial function is sufficient, the increased peripheral resistance is overcome by an increased stroke volume of the heart and by a gradual development of collateral circulation. The failure of cardiac reserve as manifested by falling blood-pressure becomes the frequent cause of peripheral circulatory disorders. de Takáts states that in treatment of these arteriosclerotic patients, who complain of intermittent claudication and later of rest pain, numbness, tingling or burning of the feet, all the vasodilators, sedatives and physical measures and also abstinence from tobacco must be utilized. It is in these cases where there is a real field for passive vascular exercise to develop and sustain collateral circulation. Mild heating by the thermal measures discussed is also in order. The author has seen a number of cases of early claudication promptly relieved by a course of inductance coil heating to the thighs. Careful heating may be also applied at home several times a day for periods of fifteen to forty-five minutes, alternating with Buerger's postural exercises. In advanced cases where there are secondary skin lesions, ulceration or beginning gangrene, rest in bed and thermostatically controlled heat applied continuously for several hours are indicated, as well as mild passive vascular exercise, possibly use of the oscillating bed.

Hypothermy (refrigeration) has been recently recommended, for reasons stated in Chapter XXXI, to safeguard against or minimize gangrene resulting from arterial occlusion. The most dramatic results from application of cold may be expected in arteriosclerotic gangrene complicating diabetes mellitus.[5] Surgery is usually contraindicated in such cases and refrigeration offers an alternative. The gangrenous leg may be packed in ice, thereby reducing catabolism of ischemic tissue and temporarily checking growth of bacteria. This procedure may make possible control of diabetic acidosis so that the patient has a reasonable chance to survive operation. It may be supplemented by application of a tourniquet distal to the proposed site of amputation. This completely isolates the gangrenous area from the general circulation. Once applied, such a tourniquet must never be removed. Hypothermy is also valuable in preparation of the poor risk patient with vascular disease for life-saving surgery, and when used as an anesthetic in these cases it has valuable advantages over conventional methods.

Thrombo-angiitis Obliterans (Buerger's Disease).—This is a progressive vascular inflammation characterized by a migrating arteritis, with secondary thrombosis. It occurs in younger individuals and it has been shown that in the large majority of cases there is hypersensitivity to tobacco present and since vasoconstrictor effects of nicotine are definite, smoking should be prohibited in any condition of impaired peripheral circulation.

In the acute stage of thrombo-angiitis obliterans, thrombosis of a segment of an artery frequently occurs, leading to complete occlusion; this segment may be quite short or may extend from the popliteals to the dorsalis pedis vessels. In the chronic stage the arteries, veins and nerves are bound together in a dense mass of fibrous tissue. After the fiftieth year the disease usually subsides or arteriosclerotic changes may take place.

The physical treatment of these conditions must be based on the amount of collateral circulation and spasm present and whether or not there are any secondary skin lesions. The general scheme of the physical treatment is the same as in arteriosclerosis.

Thrombophlebitis.—In acute cases of inflammation of a vein associated with formation of a thrombus, circulation will be aided by elevation, and normal involution of the thrombus and periphlebitis promoted by external heating. Barker and Counseller[2] advocate that the leg be elevated 30 degrees, the knee kept in extension and the hip in slightly outward rotation; the patient may move occasionally. Continuous hot packs are applied until the temperature has been normal for at least three days, until tenderness has disappeared, and until swelling has gone from the lower leg. Then the leg is lowered for two days and—ten to sixteen days after onset of thrombophlebitis—the patient is allowed up. In order to prevent development of secondary varices, edema, ulceration due to inadequate circulation, a leg support, either a solid rubber bandage or a heavy elastic stocking is applied from toes to knee before the patient gets out of bed.

The support should be rewrapped twice during the day and removed at bedtime. Ordinary activity is permitted, except long standing without walking, but when sitting or sleeping the leg should be slightly elevated for one or two months. After a few months the leg support can be permanently discarded, if there is no swelling after its temporary removal.

Mecholyl iontophoresis has been favorably reported in cases of deep thrombophlebitis by Sokolov and Meyers,[17] also by de Takáts for the softening of thrombophlebitic indurations. It should be applied in a 0.2 per cent solution, with the technique described in Chapter VIII, daily, for forty-five minutes for six to ten days, then two to three times weekly.

Acute Thrombosis and Embolism.—In these conditions combined treatment by thermostatically controlled heating and careful passive vascular exercise have been reported as of striking effect.

Care of Feet in Peripheral Vascular Disease.—In all cases of peripheral vascular disease and especially in those with signs of trophic disorders, in "inflamed" toes which are cold and in any form of infection, surgical procedures must be instituted only with utmost circumspection; small lesions must be treated with strict surgical cleanliness; any infection is preferably treated with moist wet dressings and the patient kept off his feet. de Takáts[20] quotes the following general directions for the home care of the feet, prescribed at the Vascular Clinic of the Cincinnati General Hospital:

1. Wash feet each night with neutral (face) soap and warm water.
2. Dry feet with a clean soft cloth without rubbing the skin.
3. Apply rubbing alcohol (70 per cent) and allow the feet to dry thoroughly. Then apply a liberal amount of petrolatum or toilet lanolin and gently massage.
4. Always keep the feet warm. Use woolen socks or wool-lined shoes in the winter and white cotton socks in warm weather. Use a clean pair of socks each day.
5. Use loose-fitting bed socks instead of hot water bottles, electric heaters or any other form of mechanical heating devices.
6. Wear properly fitting shoes and be particularly careful that they are not too tight. Use shoes made of soft leather, without box toes.
7. Cut the toenails only in good light and only after the feet have been cleaned thoroughly. Cut the nails straight across.
8. Do not cut corns or calluses.
9. Do not wear circular garters.
10. Do not sit with legs crossed.
11. Do not use strong antiseptic drugs on the feet. Particularly never use tincture of iodine, lysol, cresol or carbolic acid.
12. Go to the doctor at the first sign of a blister, infection of the toes, ingrowing toenail or trouble with bunions, corns or calluses.
13. Drink at least 4 qts. water each day.
14. Eat plenty of green vegetables and fruit in an otherwise well-balanced liberal diet, unless some special diet has been ordered.
15. Do not use tobacco in any form.
16. Have some member of the family examine the feet at least once each week.
17. Carry out the exercises prescribed. Do them regularly and faithfully.

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CHAPTER XXV

RESPIRATORY, GASTRO-INTESTINAL AND METABOLIC CONDITIONS

General Considerations. Bronchitis. Pneumonia. Empyema. Pleurisy. Pulmonary Tuberculosis. Gastro-intestinal Conditions. Gastric Neuroses. Constipation. Visceroptosis. Abdominal Adhesions. Intestinal and Peritoneal Tuberculosis. Diseases of the Liver. Cholecystitis. Metabolic Conditions. Rickets. Infantile Tetany. Obesity.

General Considerations.—Physical therapy measures in respiratory and gastro-intestinal conditions can be employed for combating the principal pathological changes or for alleviating one or more of the disturbing symptoms, as pain, spasm or other functional disorder. They can be directly applied to the site of the pathological changes or used for constitutional effect.

Heat is the most important, most versatile and most readily available physical measure for the relief of pain and spasm—when not caused by suppuration or an obstructive process—and for the promotion of resolution in inflammatory conditions. The time-honored methods of poulticing and electrical pads have been augmented by the more efficient radiant heat generators and by the penetrating method of diathermy, and short-wave diathermy.

Low-frequency electrical currents are useful in atonic conditions of the abdominal wall and the hollow viscera. They exert a direct effect on the abdominal muscles and a reflex effect upon peristalsis.

Ultraviolet irradiation in internal medicine may be employed either for general tonic effect by small suberythematous doses, or for a marked erythema reaction in a circumscribed area with the idea of a protein shock therapy. Such irradiation, as well as incandescent light baths, may serve for constitutional effects also, in postoperative debility and some metabolic disorders.

A combination or alternation of various physical measures for local and systemic effect forms the backbone of the treatment methods employed in health resorts. There is no reason why they cannot be similarly utilized in the treatment of many gastro-intestinal conditions in the office or at the home.

Bronchitis.—Acute and chronic types of bronchitis respond with symptomatic improvement to diathermy. In acute cases there is relief from the pain and the soreness in the chest; in chronic cases there is less cough and easier expectoration.

The technique of diathermy to the chest is quite simple. With short-wave diathermy condenser pads of suitable size are placed antero-posteriorly with ample spacing (2 to 3 inches), by towels or by felt spacing with one layer of absorbent toweling next to the skin so as to absorb perspiration and prevent burns. The shorter the wave length employed and the more powerful the apparatus the more spacing may be employed. On alternate treatments the pads may be placed laterally on the chest or treatment disks on adjustable arms are employed. With the coil field method a treatment disk with a pancake coil is more convenient. (Fig. 168.) The duration of each treatment should be from one-half hour upwards. Treatment should be given at optimal intensity. With long-wave diathermy, the simple antero-posterior technique as described in Chapter XI is applied. The strength of the current may vary from 1000 to 2000 milliamperes. Preliminary surface heating by a 1000- or 1500-watt lamp directed to both sides of the chest adds to the effect.

In chronic cases, especially those of asthmatic type, the additional use of ultraviolet irradiation is indicated. It may be employed either as general irradiation or applied to the chest only, using doses causing mild dermatitis. The marked relief given by this is explained by counter-irritation and by the mild protein shock from the irradiated area of the skin.

FIG. 294.—Short-wave diathermy to chest with condenser pad. (Courtesy of The Burdick Corp.)

A chest compress is a useful hydriatic measure for home treatment in both acute and chronic bronchitis. It is applied diagonally from under the axilla across the opposite shoulder on either side and the covering dry flannel strips are applied the same way and fastened with safety-pins. A compress applied for several hours or during the night relieves pain and diminishes coughing by easing expectoration.

Pneumonia.—In the early literature on diathermy, much has been written about its use in pneumonia; and a number of reports attesting to the favorable effect of long-wave diathermy on the pneumonias appeared in the world literature, the only controlled study being that of Wetherbee,[23] who reported a mortality of 11.1 per cent in the diathermy group and $33\frac{1}{3}$ per cent in the control group. In classical animal studies of Binger and Christie[1] the rise of temperature within the pneumonic lungs following diathermy was readily demonstrable, yet in 3 pneumonia patients in which experimental lung punctures were performed no such rise was evident. They feel that the therapeutic value of diathermy might be due to effects on the pulmonary circulation and not to local heating.

The technique of application is the same as in bronchitis. Treatments should be administered for one-half to one hour at a time and repeated several times a day, at intervals of six to eight hours, depending on the severity of the symptoms present. After resolution they may be continued about twice a day for another week in all cases where the heart is suspected of being affected.

The usual clinical effects observed in an uncomplicated case of lobar pneumonia are the relief of pain, relief of dyspnea and cyanosis, improvement of the heart action, general sedation and often an induction of sleep. All these effects are interpreted as due to an improvement in the pulmonary circulation and in the heart action. It has been reported that in the majority of cases of lobar pneumonia resolution occurred by lysis rather than by crisis, and that in those treated early with diathermy the mortality-rate was lower. Most conservative observers agree that diathermy in pneumonia may be regarded as an adjuvant measure, especially for the relief of pain and that no untoward effects have been reported in the many thousands of cases treated.

In view of the present day dramatic results with the sulfa drugs, there is much less occasion for the symptomatic treatment of pneumonias by diathermy in the early stages. Perhaps the major remaining indication for the early use of this measure would be for the possible prevention of postoperative pneumonias. Portman[14] reported at the Cleveland Clinic the immediate application of diathermy to prevent the development of postoperative pneumonia in elderly or debilitated patients and the application of diathermy to the chest of any patient who may have an unexplainable rise in temperature with increased respiratory and pulse-rate.

The late use of diathermy may also be indicated in the sequelæ of pneumonia, delayed resolution and extensive postpneumonic bronchitis.

In pneumonias and bronchopneumonias of children favorable results comparable to those in adults were reported with diathermy by Forbes.[7] In the experience of the author, luminous or infrared radiation produces in most instances clinical results nearly as favorable as those with diathermy, with much less trouble and risk.

Empyema.—The postoperative stage of this occasional sequel of acute pulmonary affections, complicated with osteomyelitis of the sectioned ribs has been benefited by diathermy directly applied through the site of infection. In postoperative cases the addition of general ultraviolet irradiation is indicated.

Pleurisy.—In acute inflammation of the pleura, external applications of heat are a well known means of relief; prolonged exposures (one-half hour every two hours) from a large luminous heat generator are of marked benefit. In selected cases diathermy may be added, with the current through the affected area. In chronic non-suppurative cases the same technique is employed in order to speed up the resorption of the exudate and to prevent adhesions.

Pulmonary Tuberculosis.—Heliotherapy and artificial ultraviolet irradiation have been extensively employed in the past two decades in pulmonary tuberculosis. Clinicians agree that progressive and active cases with high fever are not suitable for light therapy. Opinion as to its use in chronic cases is divided. Mayer[13] considers pulmonary tuberculosis *per se* not an indication for light therapy; stationary pleural tuberculosis has often been helped by it; also "hilum" tuberculosis of adults and pretuberculosis of children. Overdosage in tuberculosis may set up focal reaction similar to that of tuberculin.

Pottenger[15] holds that patients with active tuberculosis should not be subjected to direct exposure to strong sunlight, especially when the weather is very warm. The chief fear is that of a severe reaction following its employment. Such an effect can be easily avoided by proper technique. Other authorities agree that since from the clinical point of view it is well established that the sun does good through its general effect on the patient, there is no contraindication to its use in pulmonary disease. Krusen finds that there is no logical explanation for the exclusion of pulmonary tuberculosis from the list of those benefited by light therapy and Coulter and Carter[2] state that the generally listed dangers following ultraviolet radiation in pulmonary tuberculosis have been exaggerated, provided the dosage of ultraviolet is carefully regulated.

The scheme of graduated exposures to heliotherapy recommended by Pottenger is as follows: "Three minutes' exposure on the front of the body the first day; three minutes back and three minutes front the second day; six minutes front and three minutes back the third day; six minutes front and six minutes back the fourth day; nine minutes front and six minutes back the fifth day and so on. If the patient is standing the exposure quite well and tanning has well started, then exposure may increase five minutes front and back each day. One hour's exposure a day is sufficient for many patients, although others can spend most of the day with bare skins, particularly if exercising, with good effects."

For places and seasons when the exposure of patients to the direct sun's rays seems difficult, Pottenger recommends artificial radiation.

Indoor ultraviolet irradiation lacks such important features of heliotherapy as the moving fresh air with its deeper effects produced through the skin and respiration and in colder weather the uniform warming of the whole cutaneous surface with its production of sense of comfort, well-being and relaxation. (Mayer.) However, Ellman[5] reporting on ambulatory treatments at London states that light therapy (*not* heat therapy) as an adjunct to the routine treatment, in selected cases will aid in improving the physical and mental condition, definitely diminish physical signs in the chest and relieve symptoms such as cough and sputum and improve weight and sleep. He considers ultraviolet absolutely contraindicated in all exudative types.

Physicians may use light therapy in suberythemal doses as an adjunct to the constitutional treatment of pulmonary tuberculosis, provided it is applied with careful observation of the patient's reaction. It must be avoided in far advanced and toxic cases and the amount of heat rays should be restricted to a minimum at any time. There is no question about the fact that the majority of patients like light treatment and are in a much more cheerful mental state while taking it.

A proper balance of rest and exercise in tuberculosis are physical measures of paramount importance. Rest will heal tuberculosis, but it must be mental as well as physical rest. Bed rest must be maintained in a patient with constitutional signs and symptoms until the disease becomes stabilized; after that he may be allowed a graduated amount of exercise if other signs are favorable. Patients with minimal disease and positive sputum should be kept in bed until the sputum becomes negative. No patient with active tuberculosis, regardless of the stage of the disease or the presence or absence of symptoms, should be allowed to indulge in any activity to the point of fatigue. To strengthen weakened respiratory and circulatory organs after prolonged inactivity in the case of pulmonary tuberculosis, Voute[21] recommends early institution of work therapy by means of light individual gymnastics combined with massage. When the work therapy is begun, rest periods should be gradually reduced so that when the patient is discharged, he requires at the most two hours of rest daily.

GASTRO-INTESTINAL CONDITIONS

Gastric Neuroses.—Functional disturbances of the stomach may be of sensory type, gastralgia; motor type, nervous vomiting; or the secretory type, hyperacidity and hypersecretion. The diagnosis of a gastric neurosis is made if local signs associated with those of some functional nervous disorder are present and no definite pathological changes can be proven. The treatment of the nervous condition is of paramount importance.

Diathermy is a useful adjunct for local treatment. Short-wave diathermy may be administered by antero-posterior condenser pads or by a pancake coil placed on the abdomen. With long-wave diathermy a 4 by 6 inch plate electrode is placed posteriorly, and a somewhat smaller one—4 by 4 inches—over the epigastrium. Treatments should last twenty-five to thirty minutes and a current strength of moderate intensity, 1000 to 1300 milliamperes, should be used with long-wave diathermy.

The galvanic current may serve as an alternate measure in selected cases. It is employed through moist pad electrodes of the same size and position as in diathermy. The current is applied for about thirty minutes and its strength should be from 10 to 15 milliamperes.

General ultraviolet irradiation as well as various hydrotherapeutic measures may be added for tonic effect.

Constipation.—Each case of constipation is a clinical problem in itself: it may be only a symptom accompanying a pathological condition of the gastro-intestinal tract, or it may be the direct outcome of incorrect habits or living conditions. From the therapeutic standpoint it has been found practicable to adopt a classification into atonic and spastic types; this also serves as a convenient guide in the consideration of rational physical therapy.

The *atonic type* of constipation which is by far more frequent is characterized by weakness of the large intestine; this may be brought about by many factors, among them bad habits of eating, neglect of the urge of defecation, congenital weakness of abdominal muscles and weakening diseases. In its management, general hygiene, diet, judicious medication and mental treatment are effectively aided by physical agents exerting general and local stimulation. Among these agents belong massage, exercise, low frequency electrical currents, hydrotherapy and light therapy.

Massage is the simplest and most readily available stimulative measure in the treatment of constipation. When applied to the abdomen its main effect is to increase the tone of abdominal muscles and to bring about increased peristalsis by reflex action. No amount of massage can actually move the abdominal contents; neither can the massage have much effect on the tone of the intestinal musculature and of back and pelvic muscles; hence in cases of real ptosis and relaxation of the pelvic floor, more effective forms of stimulation must be employed.

In carrying on abdominal massage it is far from necessary that it be vigorous or prolonged. Slow and gentle movements applied at a rate of about twelve a minute and with a pressure only to dent the abdominal wall are sufficient. The patient lies relaxed on a low couch and gentle rhythmical stroking is applied along the ascending, transverse and descending colon. After the patient has learned how to relax under these stroking movements, gentle kneading and rolling and finally rhythmical vibration of the various parts of the abdomen are performed. All of this should not take more than ten minutes. There is no reason why the physician himself should not apply abdominal massage with the simple technique recommended. Massage should be given daily, then every other day for several weeks; in many cases results show after the first few treatments; if no improvement is noted within two weeks, massage should be discontinued.

General massage may be conveniently prescribed in such cases of the atonic type where stimulation of the general circulation and muscle tone appear desirable. Ten to fifteen minutes of general massage, following the abdominal massage, is all that is indicated, especially when active exercises also form part of the program. No massage treatment should leave the patient all tired out; the strength and extent of the massage must be adapted to the musculature and reflexes of the patient.

Electrical muscle stimulation combined with massage or applied alone serves to tone up the abdominal and pelvic muscles by active contractions; it is the method of choice in atonic cases where massage is not practicable or which prove to be more resistant, or where direct stimulation of the pelvic floor is desirable. Electrical stimulation, like massage, also aids peristalsis by reflex stimulation and increases glandular function and the venous return from the abdomen to the heart. Reynolds[17] proved experimentally that electrical currents exert no direct stimulation of the intestinal walls and the tonic effects enumerated are due to reflex action. The author has obtained equally favorable results by a variety of currents, such as the surging faradic, the interrupted slow sinusoidal and the modulated alternating current. Hence, as long as the type of current employed and the technique of application produce efficient stimulation within pleasant toleration of the patient, it does not matter particularly what make of apparatus and what modification of current is used.

The method employed by the author is as follows: A large moist pad electrode, 5 inches wide and 7 inches long, is placed over the abdomen and another one of equal size directly opposite, under the back of the patient. Either the surging faradic or modulated alternating current (Morse wave) is used; the current strength is gradually increased until definite contractions of the abdominal wall are evident; it should be the endeavor to synchronize these contractions with the rate of respiration, producing about 18 to 20 contractions per minute. Patients seem to tolerate the modulated alternating current better; this can be explained by the fact that the shorter duration of each impulse has a minimal sensory irritating effect. At successive treatments a current of increased strength may be administered, and it can be generally noted that in patients with ptosis the abdomen becomes more firm and bowel movements more regular. Treatments should last from ten to twenty minutes and be administered every other day for several weeks.

Voluntary exercise forms an indispensable part in treatment of chronic constipation. General exercise serves to improve the general physical state and to react indirectly on the gastro-intestinal function; it may be employed in both types of constipation. Abdominal exercise serves specifically to strengthen the abdominal and respiratory muscles and is chiefly applicable to atonic states.

For general exercise the outdoors is preferable, especially when taken regularly and not in one big sweep over the week-end. Tennis, golf, horseback riding, running or swimming, done in moderation and within individual taste and endurance, are beneficial; walking is of comparatively little direct value, as shown by the fact that many persons in occupations which require a great deal of walking, such as letter-carriers, are constipated.

Abdominal gymnastics are valuable when prescribed and carried out systematically within individual tolerance. Exercises that necessitate holding of the breath or keeping the lower trunk muscles in strong continued contraction are not suitable. There is no end to the variety of different forms of active and passive exercise in the treatment of constipation. Two simple sets of exercises which can be easily demonstrated to every patient are as follows:

A. Exercise in lying posture; resting flat on the back with hands on the sides.
1. Deep breathing; inhale slowly, hold breath for five seconds; exhale slowly.
2. Raise right thigh with leg extended.
3. Raise left thigh with leg extended.
4. Raise both thighs with legs extended.
5. Raise thighs with knees bent.
6. Raise body upon thighs.

B. Exercises in standing posture; legs together, with hands on hips.
1. Bend trunk forward as far as possible.
2. Bend trunk backward as far as possible.
3. Carry trunk to right side.
4. Carry trunk to left side.
5. Rotate trunk to right.
6. Rotate trunk to left.

Exercises are preferably carried out upon rising in the morning; if this is not practical, an hour before lunch or dinner. They can be done on a bed with firm springs and mattress, but still better on the floor, on a folded woolen blanket. They should be performed slowly, each exercise three times the first day and increased by one each day until ten to fifteen is reached. A few minutes' rest in supine position is advisable afterwards; patients must be advised to acquire the habit of full body relaxation whenever they rest. Exercises should be done daily for many months; they may be varied according to the individual conditions. (Figs. 270–275.)

The *spastic type* of constipation is characterized in its severe forms by contracted, sensitive abdominal walls, tight anal sphincter and typical pencil-shaped stools. It occurs frequently in patients with signs of neurasthenia who present an endless story of their symptoms and who anxiously watch their stools. A mild laxative may cause marked colic in these patients because of the spasm of the intestines and the emptiness of the rectum. In the treatment, general nervous relaxation and sedation are indicated, while heat is the chief standby of local treatment.

In the general or constitutional treatment of spastic constipation general tonic forms of physical therapy are useful, selected according to the individual circumstance. A general light bath in an electric cabinet or under a large heat lamp, followed by a mild alternate hot and cold douche (Scotch douche) may be administered; likewise general irradiations from ultraviolet sources and general forms of exercise, outdoor and indoor, should also be considered.

For the local treatment heat, the age-old measure for the relief of sensory or motor nerve irritation, is the sovereign remedial agent. In cases of mild local spasm, exposure for half an hour twice a day under a small luminous heat lamp or infrared generator will be beneficial. In more severe forms the penetrating heat effect of either short- or long-wave diathermy is the method of choice. Two large electrodes are placed over the abdomen and back respectively, and from 1500 to 2500 milliamperes of current are employed for one-half hour, four times a week for four weeks. Rendall[16] saw favorable results by diathermy in a large number of obstinate cases which had resisted treatment by diet and other measures. Zeiter[24] reports encouraging results from short-wave diathermy as an adjunct in treatment of irritable colon, the term synonymously applied for spastic constipation.

Hydrotherapy in either form of constipation may utilize the mechanical cleansing effects of moving water or the stimulative or sedative effects of its temperature. A glass of cold water on an empty stomach on arising acts as a stimulant of peristalsis in many people; especially when first employed it produces a soft movement within half an hour. The water should never be so cold as to cause a chilly sensation. In some persons, a glass of fairly hot water exerts the same effect. Hence, in atonic types of constipation these mild effects can be utilized.

Water by rectum, in the form of an enema, may be used with advantage at the beginning of treatment in mechanically cleansing the rectum and colon. Tepid water with some bicarbonate of soda and witch hazel serves best for a cleansing enema. A cold water enema at a temperature of 60° to 70° F. is more irritating than a cold drink and is indicated only occasionally. Cold water may also be employed externally in institutional practice as a cold sitz bath or cold jet douche, alternating with a hot jet—the regulation Scotch douche. In spastic conditions these forms of treatment are strictly contraindicated; however, hot sitz baths at 110° for fifteen minutes and hot enema of the same temperature may be of service.

Colonic irrigation has only a limited place in the treatment of constipation. When there is an accompanying colitis or a good deal of intestinal putrefaction, suitable medicated irrigations may be temporarily employed.

Visceroptosis.—Postoperative and Postpartum Weakness of Abdominal Muscles.—These conditions present common features of dysfunction, namely lack of tone of the musculature of the stomach and intestines and often weakness of the abdominal walls. Graduated muscular exercise by low-frequency currents and reflex stimulation of peristalsis tend to improve the tone of the musculature of the visceral tract. It should also aid the venous return from the abdomen to the heart and stimulate glandular function. The technique of treatment is the same as described for atonic constipation.

In atonic abdominal muscles after child-birth it is advisable to tone up the pelvic muscles also by employing a vaginal or rectal electrode and a dispersive electrode on the abdomen.

Abdominal Adhesions.—Peritoneal adhesions are a frequently suspected cause of pain and other distress following operations and inflammatory conditions in the abdomen. They form either as a result of a local peritonitis or traumatism at the time of an abdominal operation. An exercising current or diathermy is equally indicated in the management of this disability and the author has had some excellent results from the combined use of the two modalities with the apparatus and technique described in Chapter XI. It is advisable to start with diathermy for five to ten minutes and then turn on the surging low-frequency current and continue the two for ten to fifteen minutes. Treatment should be repeated first daily and then less frequently.

Intestinal Tuberculosis.—The prognosis of this frequent complication of pulmonary tuberculosis is generally pessimistic. Erickson[6] holds that ultraviolet is one of the major therapeutic measures and should be used until better methods of treatment become known. In a study of sanatorium cases treated with ultraviolet 85 per cent showed some symptomatic improvement and of these 27 per cent had entire relief from symptoms and 47 per cent were very much improved. Relief came generally within a month, entire loss of symptoms within three to four months. In a study of Coulter and Hardt,[3] patients who did not receive ultraviolet radiation showed a lower percentage of improvement than the same groups receiving ultraviolet radiation. The radiation apparently decreases the symptoms or at least keeps them stationary in the large percentage of all groups, with or without calcium therapy.

Peritoneal Tuberculosis.—Light therapy always deserves a first trial in this condition. Mayer[13] states that the serous exudative type generally responds to light irradiation, both in children and in adults. The dry proliferative form, usually adhesive, is more refractory. When there have been ulcerations and large caseous lymph nodes, as commonly seen in children, the results are most unsatisfactory. Stubenbord and Spies[19] found light therapy most satisfactory in chronic plastic adhesive types of cases with localized peritonitis.

As a source of irradiation, in both intestinal and peritoneal tuberculosis, sources combining a preponderance of ultraviolet (mercury vapor lamps) are generally preferable to sources containing a large amount of heat radiation. Treatment must be applied over the entire body in suberythemal doses and not, as it is often erroneously ordered, to the abdomen only. A mild degree of fever is no contraindication in these cases but it is advisable to treat such cases only on alternate days, so as to enable subsidence of occasional febrile reactions after irradiation. It is necessary to continue treatment for many weeks, although it usually quickly results in the disappearance of pain, especially in children. Rest, approved diet and fresh air form other important essentials in treatment.

Diseases of the Liver.—The literature contains a number of reports of the beneficial effects of diathermy in chronic diffuse hepatitis, hypertrophic cirrhosis and mild forms of liver insufficiency of toxic origin. Animal and human experiments through the means of a duodenal sound proved that diathermy increased both the quantity and quality of bile (Goldgruber[9]). Before diathermy only pale-green bile flowed through the sound; immediately after turning on the current, a strikingly dark bile in large quantities flowed out. Goldgruber used diathermy in treating catarrhal icterus, salvarsan jaundice, subacute and chronic cholangitis and in early cases of cirrhosis. After a couple of treatments the urine became free of bilirubin and contained only urobilin and urobilinogen in great quantities. Goldgruber assumes that the diseased liver parenchyma regained during diathermy treatment its power of dealing with the urobilin poured into the intestine, thus taking from the kidneys the work of secretion. Treatments of two hours' duration were given. Experimental investigations by Couperus and Moor[4] in dogs with biliary fistulæ showed that diathermy to the liver increased the secretion of bile from 7 to 17 per cent during a twenty-four hour period, while during the twelve-hour period immediately following the application of diathermy the increase varied from 8 to 46 per cent.

Cholecystitis.—In subacute and chronic cholecystitis diathermy is the principal treatment, and to diminish the volume of painful and enlarged livers there is nothing that equals diathermy (Weiss[22]). In cholecystitis repeated applications enable the liver and gall-bladder to function more satisfactorily. The treatment can have no curative action on a sclerosed gall-bladder, on those which are packed with calculi, on constriction of the gall-bladder or in cholangitis with jaundice.

The author found diathermy of definite value in chronic cholecystitis, as an adjunct to medicinal and dietetic régime. In recurrent attacks of pain not due to obstruction or infection diathermy generally tends to shorten the attack and keeps the patient comfortable without recourse to morphine. A dispersive electrode, 5 by 7 inches, is placed under the center and somewhat to the right of the lumbar spine and a smaller electrode, 4 by 4 or 5 by 5 inches, is laid over the gall-bladder region in front. In securing the anterior electrode one must be careful to keep away from the edge of the costal arch or else bridge it over evenly in order to avoid uneven contact or too much pressure. With long-wave diathermy from 1000 to 1500 milliamperes of current are usually well tolerated. Treatments should be kept up for at least one-half hour each time and be administered daily or twice a day at first and then less often. Short-wave diathermy offers a simpler technique with a pancake coil over the liver region.

Weiss advocates diathermy as an aid in cholecystography, especially where there is delayed filling or poor visibility of the gall-bladder shadow. The best results are obtained three to five hours after the intravenous, oral or combined use of the dye; it permits better visualization even shortly before cholecystography for it will cause the gases in the intestine to diminish and a denser shadow of the gall-bladder will be obtained.

METABOLIC CONDITIONS

Rickets.—Ultraviolet irradiation from the sun or from artificial sources is a potent and reliable specific in the treatment of rickets. Exposure must be gradual and proceed according to the child's susceptibility. Gerstenberger and Hartman[8] found that exposure to a mercury vapor lamp in doses of erythema units given once a week for five to eleven weeks is sufficient for the care and prevention of rickets. Luce-Clausen[12] states that the average case requires irradiation every other day for a total period of four weeks, but severe cases may require eight or ten weeks. If treatment is begun after January, it will not be necessary to repeat the course of treatment during the winter, but if it is begun in the autumn, a second series of irradiation should be given before March.

Infantile Tetany.—This symptom-complex occurring in rickets when the blood calcium is low, will yield to ultraviolet irradiation. The treatment of choice, according to Laurens,[11] is a combination of calcium salt (lactate or gluconate), a diet low in phosphate and optimal in vitamin D. If ultraviolet is used an initial increase of nervous irritability may be expected. Latent tetany may become manifest when rachitic infants are irradiated, if sufficient calcium is not available, due to the suddenly increased mobilization of calcium and deposition in the growing bones. Preliminary medication is therefore necessary in these cases. The same considerations prevail in the treatment of spasmophilia.

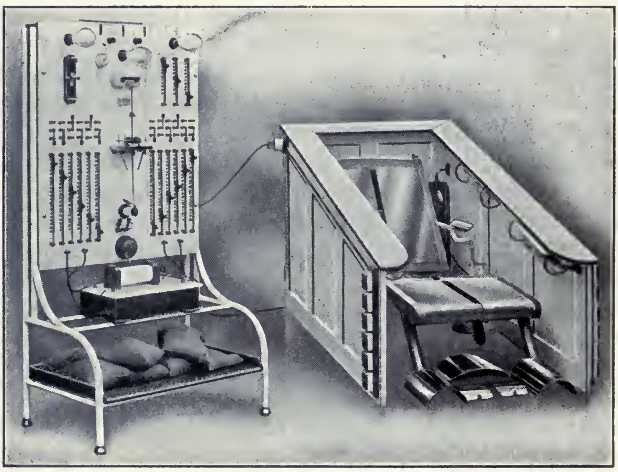

Fig. 295.—Bergonie apparatus for general faradic stimulation. (Courtesy of the Medical Supply Association, Ltd.)

Obesity.—Obesity is a general systemic disorder, in which either exogenous causes, such as overeating and lack of exercise or endogenous causes, such as endocrine imbalance, predominate; at the bottom of it all there is always the uncertain factor of constitutional predisposition—one that keeps lean people as they are in spite of all they eat and keeps others stout in spite of all exercising and dieting. Many of the commercialized obesity cures carried on by self-styled experts only add to the already existing disorder. No therapeutic measure directed against obesity can be called rational unless one first makes the attempt to combat the underlying pathology and, therefore, it must not be inferred that the method described constitutes the whole treatment of obesity. This condition is of such complex and diverse origin that the treatment must be individualized in accordance with the causative factors.

Massage has only very limited value in the treatment of obesity although the lay mind is made to believe that it is possible to break up "fat" and stout ladies hopefully crowd into commercially advertised reducing studios where underpaid slaves maul them in long sessions of vain efforts. Only a judicious use of general massage may exert some effects on metabolism in obesity. For local conditions, like an obese, relaxed abdomen the following scheme of massage treatment may be prescribed: Begin with firm stroking movements in a longitudinal direction, from the symphysis towards the costal arch. After a few minutes alternate with deep kneading by one or two hands, then percussion with the open hand. Conclude treatment with another series of deep, stroking movements, making them end in light stroking.

Electrical muscle exercise for weight reduction has been for many years employed, by means of a modified faradic apparatus, constructed by Bergonie in 1913. The output of the secondary winding of a powerful faradic coil is led to a special chair, which has six metal surfaces for the various parts of the body. Six movable electrodes fit over the other parts. The undressed patient is placed on the chair, and firm contact is made between the electrodes and the various body surfaces by moist towels. By adjusting the rheostats controlling the six circuits, graduated contractions are started in the various parts. A routine course of treatment (E. C. Titus[20]) consists of an initial application of one-half hour, with an increase of ten minutes each day, up to one hour in duration. After three or four weeks, treatments are administered every other day and then at longer intervals, if indicated, for a total period of from six to ten weeks.

It is claimed that by exercising passively a large group of muscles a reduction of fatty tissue can be accomplished without any strain on the heart and for this reason the method has been recommended as a form of exercise in conditions of chronic arthritis. Turrell calls attention to the healthy, vigorous and athletic appearance of patients who have undergone passive ergotherapy—as the method has been named—in contrast to the victims of a starvation diet with their pinched countenances, parchment skins and shrunken and lusterless eyes.

In spite of its enthusiastic advocates, the Bergonie method is at present only employed in a very limited measure. While there is no doubt that weight reduction by electrical means, as described, is possible to a certain extent, it can be considered only as an adjuvant measure to a general plan of medical treatment.

Heald[10] states: "Bergonie's chair is nothing more than a clever contrivance for bringing easily controlled and graduated interrupted faradic contractions to the muscles of the body, particularly to those of the abdomen and buttock. It is more effective as a treatment for chronic constipation than it is for reducing fat, the original purpose of the instrument."

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CHAPTER XXVI

CHRONIC ARTHRITIS AND FIBROSITIS

General Considerations. Rôle of Physical Therapy. Classification. Grading of Cases. Physical Therapy Measures in Arthritis: Thermal Measures, Mechanical Measures, Counterirritant Measures. Spa Treatment. Scheme of Physical Treatment. Osteo-arthritis. Rheumatoid Arthritis. Gonorrheal Arthritis. Spondylitis. Gouty Arthritis. Acute Arthritides. Fibrositis. Pathology. Classification. Diagnosis. Treatment. Panniculitis. Results of Treatment.

General Considerations.—From the low ebb of interest hitherto shown by the medical profession and the public in chronic arthritis and rheumatoid conditions, a very definite change of attitude has taken place in recent years. Economists have shown that rheumatism presents one of the most important problems because of the long and expensive medical treatment required, the loss of earning power of those affected and the economic consequences on the patients and their dependents.

With special attention focused on the rheumatic problem, there are now in some of our large centers groups of specialists actively interested in research work as well as in clinical observations. However, chronic arthritis is equally prevalent in cities and in the country. Its early recognition and treatment, as well as the comforting of those in its later stages, must always remain in the hands of the physician in the field, and therefore it is up to the general practitioner to learn to attack rheumatism efficiently and intelligently in its incipiency. This demands more than the prescription of a few pills, the administration of a stock vaccine or the perfunctory advice to "bathe" in hot water. It requires adequate teaching in medical schools and familiarity with the basic concepts of arthritis and all recognized means of its treatment.

Most medical men agree on two major concepts of chronic arthritis: (1) Chronic arthritis is a constitutional disease with local changes in the joints as well as disturbances in the circulation and general metabolism. (2) Chronic arthritis is a disease of varied etiology and of varied types, and hence there is no single method of treatment which is applicable to all its forms.

It is now generally recognized that the focal infection theory of rheumatism has been overemphasized in the United States for many years. Abroad there is more inclination to accept a theory of a hyperergic response of a constitutionally and hereditarily predisposed organism. There are many reasons to support the view that a lowered body resistance due to a weak constitutional make-up is one of the principal factors, if not the main factor, responsible for the development of chronic arthritis. Such hereditary weakness of the mesenchymal apparatus or the lack of sufficient defense mechanism of the mucous membranes may explain frequent colds as well as the tendency to focal infection. The favorable response to treatment measures directed to overcoming the lack of body resistance corroborates this concept.

Similar considerations prevail to a large extent regarding the etiology and treatment of the large group of rheumatoid conditions, or non-articular manifestations of rheumatism, such as fibrositis, panniculitis, muscular rheumatism, bursitis and certain forms of neuritis.

Rôle of Physical Therapy.—Physical measures have been used since ancient times for the treatment of chronic arthritis, as evidenced by the pilgrimage of rheumatic sufferers to hot springs. Modern clinical research has taught us a better understanding of the rationale of heat measures, and the evolution of physical therapy has added many effective measures to the fight against the disease. Today physical treatment measures fill an important rôle in the complex therapeutic problem presented by the necessity of combating allergic, climatic, dietetic and hygienic factors, of correcting dysfunctions of the skin, endocrine glands and gastro-intestinal system, of relieving nervous and functional disorders and of eliminating demonstrable bacterial and focal infection, as well as ameliorating an arthritic constitution. General or systemic physical measures may serve as part of constitutional therapy for the increase of circulation and metabolism, the promotion of activity of the digestive tract and the correction of faulty body mechanism. Physical measures locally applied serve to prevent and relieve local arthritic changes: pain, stiffness, exudation, muscular atrophy and weakness. There is, of course, often an interplay between general and local effects. A statement of the British Ministry of Health[5] reads, "almost every case of chronic arthritis at some stage of the disease requires *physical treatment,* usually consisting of the application of heat in some form, either alone or together with massage and movement. No scheme of treatment for chronic arthritis can be considered complete unless an extensive range of physical methods of treatment under skilled direction is available. There appears to be a rapidly increasing demand for such treatment." Pemberton[13] states that physical measures have probably as much value in the treatment of arthritis in its early stages as any others at our disposal, although their value is far from being appreciated.

Classification of Rheumatic Diseases.—The generally accepted division of rheumatic diseases into three groups is useful as a basis for consideration of their pathology and for our therapeutic endeavors.

1. **Rheumatic Fever.**—Acute and subacute rheumatism, with more or less fever, affection of several joints, at once or in rotation and responding, as a rule, to antipyretic medication (salicylates). Physical therapy plays little rôle in this condition.

2. **Chronic Joint Changes.**—(*a*) *Osteo-arthritis* or *hypertrophic arthritis* is usually not accompanied by fever and has a gradual onset. It is often at first confined to one large joint; it affects fewer and larger joints, especially the knee and hips; there is grating, lipping and formation of osteophytes.

The average patient with osteo-arthritis is usually a well-nourished individual past middle age; trauma, overuse or metabolic disturbance are the most frequent causative factors, and not infection. Early cases of this type as a rule can be almost completely relieved by suitable physical measures in conjunction with a suitable dietetic regimen and regulation of habits.

(*b*) *Rheumatoid arthritis* (infective periarthritis or atrophic arthritis). Primary degeneration of the cartilage takes place, although the synovial membrane is generally the site of the greatest changes at first; the destruction of cartilage follows as the disease progresses; new formation of bone or cartilage by perichondrial proliferation may also take place. Usually many smaller joints are affected, especially the proximal interphalangeal joints; the lesions are often bilaterally symmetrical.

Rheumatoid arthritis occurs in younger persons, usually in a poor state of nutrition. Infection may play a rôle in its onset, and it usually affects many of the smaller joints. In this condition the heat-regulating apparatus is often disturbed and the circulation is out of order, as manifested by its variations in the skin and extremities, especially the fingers and toes. Vasomotor control is unstable. The basal metabolic-rate is changed and the blood-pressure is low. Function of the gastro-intestinal tract is poor, and there is always secondary anemia. It seems as though the entire defense mechanism of the body is below par. In this syndrome the entire range of available physical measures must be drawn on to aid the general medical treatment. Thermal methods acting as general alterants on the constitution are of especial value. The prognosis is always doubtful so far as full recovery is concerned, but patients treated early and efficiently almost always can be kept comfortable and deformities can be prevented.

(*c*) *Special forms of arthritis.* Other well-defined types of chronic arthritis are gonorrheal, gouty and traumatic; spondylitis deformans may also be considered a special type, although its pathology is that of the rheumatoid group. Physical measures of treatment are indicated in all these types and are of almost specific value in the traumatic and the gonorrheal.

3. **Non-articular Manifestations.**—Muscular rheumatism (myalgia) including fibrositis, lumbago, bursitis and certain forms of neuritis.

Physical therapy plays a most important part in the treatment of chronic joint changes as well as of non-articular manifestations.

The principal factor in the origin of rheumatic diseases and colds seems to be a choking of the arterial blood supply, as substantiated by the fact that all effective measures in rheumatism produce hyperæmization.

Grading of Cases.—The differentiation of chronic arthritis into its various types is not sufficient for the purpose of prognosis and planning treatment. There are many mixed or uncertain types of chronic arthritis. In many of these cases, as in the well-determined types, the amount of involvement of the joints is the most important question for the planning of treatment. One clinician recently emphasized the similarity of a chronic arthritic joint to that of a rusty hinge on a farmer's gate. It is evident that so far as the possibility of relief of the local "rustiness" by physical and other measures is concerned, the amount of involvement is more important than whether it is caused by osteo-arthritis or by rheumatoid arthritis. Hence the desirability of grading chronic arthritis according to the degree of involvement.

A practical system of grading into mild, moderate, severe and extreme cases, based on combined clinical and radiological findings, is described by Taylor[23] as follows:

1. *Mild* or *first degree arthritis.* Patients are ambulant, usually are able to continue their normal occupations and have no demonstrable joint changes aside from soft tissue swellings. Pains or aches are felt, but there are only slight decalcification and "lipping," although there is intra- and extracapsular swelling. These cases offer the best prognosis.

2. *Moderate* or *second degree arthritis.* Patients may be prevented by joint trouble from continuing at work, but they can usually walk about

and take care of themselves. The joint space is definitely altered, there being loss of cartilage or bone substance, moderate decalcification, capsular swelling and adjacent tissue atrophy. There is definite and prolonged localized limitation of movement, with definite osteophytes or spur formation, and local hypercalcification. Prognosis is fairly hopeful under adequate treatment.

3. *Severe* or *third degree arthritis.* Patients are so incapacitated by demonstrable joint lesions that they are unfit for work and are dependent on others for proper care. They may walk for short distances but are usually limited to bed and chair existence. There are joint subluxations, deformities, local ankyloses, marked decalcification and hypertrophic changes, osteophytes and spurs. The outlook is serious. Such patients need institutional treatment and training to preserve and regain as much joint function as possible.

4. *Extreme* or *fourth degree arthritis.* Patients are completely incapacitated and bedridden. There may be little or no pain when the active disease has subsided, and general health may be satisfactory. Joint changes are extremely widespread; there is much destruction, and bony ankyloses accompany marked hypertrophy. The outlook is poor.

The grading of arthritis is essential for prognosis, as well as for recording cases and judging benefits of different forms of treatment. It is evident that measures directed towards improvement of circulation and reduction of swellings can expect favorable response chiefly in the first two grades of the disease. When one encounters unexpected clinical results in advanced cases, it may be explained by the fact, that in chronic arthritis many of the painful processes are located in the periarticular tissues, which respond well to appropriate physical treatment. No amount of late treatment will replace a destroyed joint cartilage or remove excessive bony deposits. In such advanced cases, however, orthopedic and surgical methods still hold out hope for a reasonable amount of improvement.

Physical Treatment Measures in Arthritis

Table 52 shows the large number of physical measures available in chronic arthritis. They are in fact variations of only three basic treatment principles: heat, exercise and counterirritation.

TABLE 52.—PHYSICAL MEASURES IN CHRONIC ARTHRITIS

Thermal	Thermal and Mechanical
Hot bath	Underwater exercise
Radiant heating	Whirlpool bath
Paraffin bath	Counterirritant
Mud pack	Galvanic current
Hot air douche	Ionization with vasodilators
Diathermy, long and short wave	High-frequency (Oudin) current
Artificial fever	Ultraviolet rays (mercury vapor lamp)
Mechanical	Thermal and Counterirritant
Rest	Natural sunlight
Massage	Carbon arc lamp
Exercise, active	Galvanic bath
Exercise, passive	
Exercise, electric muscle stimulation	
Colonic irrigation	

These measures may be applied either locally or systemically The selection of a physical treatment measure and its combination with others must depend on the type, stage and extent of the arthritis and on the subjective complaints of the patient. The experience of the physician and his location also are factors in the selection from the available measures. The reason for the desirability of a variety or intermittency of physical measures, as well as the combination of several, is that some patients with chronic arthritis are more responsive to certain physical measures than to others and that certain stimuli lose their effect after a time. It is most desirable in some cases that simpler treatment measures be carried out systematically in the patient's home.

Thermal Measures.—Heating measures are potent agents in influencing circulation and metabolism. Rheumatic exudations have been likened to smoldering foci of disease, and heat, properly used, often effects their resorption. General thermal measures act as constitutional alterants.

LOCAL HEAT TREATMENT has, as its object, the increase of local blood and lymph circulation and local tissue metabolism, promotion of resorption and restoration of function. A highly desirable effect of suitably mild local thermal applications is the relief of pain, the symptom which, next to stiffness, is usually the most bothersome.

Heat lamps and infrared radiators enable simple yet efficient "dry" heat applications at the office and in the home. They have largely replaced the former cumbersome dry baking apparatus and light boxes. For home treatments patients should be instructed to use these appliances for one-half hour two or three times a day over the affected joints. Such heating should be followed by gentle stroking massage. Well-planned home treatments help to keep patients comfortable and allow the bridging of the time between office visits.

In painful acute and subacute conditions, patients can bear only mild radiant heating. In such cases thermostatically controlled heat appliances are of definite value because they can be regulated to furnish a temperature just comfortable to the patient.

Diathermy is the most efficient procedure of heating the deeper structures and has been satisfactorily used for many years in treating the larger joints and the spine. In osteo-arthritis localized in such parts, diathermy is almost specific for local relief of pain, promotion of resorption and restoration of function; it also lends itself easily to combination with other measures. In the frequent bilateral knee involvement of the osteo-arthritic type in middle-aged women, diathermy combined with suitable rest usually gives complete relief. In traumatic arthritis, diathermy followed by massage or other mechanical agent is likewise the line of first attack. The methods of applying diathermy to different joints have been presented in Chapter XI.

The usual technique of long-wave diathermy is that of transverse application; if more of the periarticular structures are affected it may be alternated with the cuff method. The longitudinal method of treating the entire extremity may be advisable where several joints are involved in the same extremity.

Short-wave diathermy gives the same clinical results as long-wave diathermy, but its technique is more simple and more flexible; especially the inductance cable or coil field method is valuable for warming up an entire extremity. Warren[25] states that the effectiveness of diathermy is enhanced very materially by prolonging the treatment for periods of from two to eight hours, with short rest periods of five to ten minutes every two to three hours. Such treatments undertaken one to three times a week for a month will often be sufficient and are far more effective than twenty to forty minute treatments three to five times a week over the same period.

The *paraffin bath* is most effective in the treatment of involvements of the hands and feet, offering an even comfortable form of heating, which leaves the skin in a condition of velvety hyperemia. Another useful alternate for treatment of fingers or other painful small areas is the hot air "douche," an ordinary hot air dryer held on a stand and blowing hot air for ten to thirty minutes against the painful part.

Mud packs consist of application of smooth plastic material which acts like a warm wet compress, maintaining its temperature for a long time and leaving the skin in a warm velvety condition. This treatment is quite cumbersome, requiring a suitable mud to begin with and skilled technical preparation; hence it is chiefly a method to be used in institutions or spas. Claims for radioactivity of muds have not been proved.

General Heat Treatment has as its object the stimulation of the general circulation and the increase of body metabolism; the local changes are only indirectly affected, yet in many instances, following general thermal treatment, there is a decrease of pain and swelling and functional improvement in the affected parts.

The *hot bath* is the simplest and most universally available general thermal measure. It may be started at a temperature of from 96° to 99° F. and gradually carried up to 102° F., employed from five minutes to one-half hour, two or three times a week. It should never exhaust a patient. According to Warren[25] the short hot bath is very successful as a routine measure at home; even in advanced infectious arthritis in old persons, it usually results in the immediate subsidence of symptoms, a gain of 10 to 15 pounds of weight and a feeling of rejuvenation. He warns about raising the mouth temperature of patients above 101° F. in the bath, for it is apt to be followed by faintness, weakness and prostration. During the cold weather period a great many patients of the older group can be kept quiescent by this procedure when used regularly three times a week and, occasionally, as often as three times a day or enough to relieve symptoms of acute exacerbation. If one or several joints are particularly slow in responding, the application of additional heating to these joints is indicated.

Electric cabinet baths are being employed in the institutional treatment of chronic arthritis of the robust type. Eight- to fifteen-minute treatments may be administered, followed by a tepid shower and a gentle rub down. Patients must rest from one-half to one hour after a light bath.

General heating may be conveniently administered in a physician's office by large radiant heating units—incandescent lamps and infrared radiators of 1000 to 1500 watt output applied for half an hour to one hour. It may also be obtained from high-frequency sources in the form of general diathermy, short-wave diathermy, or in a fever cabinet. Such general heat treatments may be used once or twice a week, interspersed with local treatments at home or at the office.

Artificial Fever Treatment.—Artificial fever treatment is indicated only in cases of moderate severity which apparently resist all other forms of treatment. A series of treatments at a moderately high temperature (102° to 104° F.) seems to be preferable; some of the good results obtained by a systematic cure in the hot spas are undoubtedly due to the artificial fever production by the prolonged hot baths. Krusen[10] estimates that about 30 per cent of patients treated with artificial fever improved significantly. Warren[25] states that while the effect of fever treatment in younger patients with predominantly soft tissue proliferative processes is only maintained for a week or a month at the most, older patients and especially those in which joint destruction is a primary factor are probably the most effectively treated by this means. To his great surprise several cases with degenerative arthritis have been markedly relieved over a long period of time following a single artificial fever treatment at 40.5° C. (105° F.) maintained for four hours.

Mechanical Measures.—*Rest.*—Rest is one of the most important and most frequently overlooked measures in the effective treatment of chronic arthritis. Pain or inflammation, whether of traumatic or of infectious origin, is Nature's way of enforcing rest, which is the first requisite for repair in all joints with pain aggravated by movement. Placing the joint at rest either in bed in the most favorable position or by support in light splints or suitable bandaging is a physical therapeutic measure of prime importance that is not sufficiently often appreciated. Not until a joint at rest is without pain, *i. e.*, without inflammation, should it be exercised. Chronic fatigue is considered one of the chief factors in arthritis; therefore general bodily and mental rest are of great importance in the nervous, anemic, overworked patient of the rheumatoid type. Rest should be prescribed systematically, with so many periods daily or one or two entire days a week. If it were economically possible in the early stages of this disease to institute a complete rest cure of several months, many more patients could make a complete recovery. Attempts to make such arrangements have been undertaken in England in connection with large rheumatic treatment centers. Bach[1] states that rest in bed helps the undernourished patient to gain weight and affords an opportunity to remodel the body by correcting functional deformity, usually due to faulty posture, and by restoring normal body mechanics. Relaxation must be taught by the technician. Certain positions should be assumed daily for short but increasing periods. The patient lies supine, with a small hard pillow placed beneath the midthoracic spine. Voluntary exercises, starting in recumbency, are taught to increase chest capacity by increasing diaphragmatic excursion and by strengthening other muscles of respiration, to improve tone and increase power of anterior and lateral abdominal, gluteal, quadriceps and hamstring muscles and muscles of the foot. Later, exercises are done in the sitting and standing positions. Deformity must be corrected and shoulders, wrists and knees must be put in best positions.

Active and passive exercise is indispensable in the treatment of almost every patient with chronic arthritis for the maintenance of mobility around the affected joints, correction of inactivity or atrophy of the muscles and prevention of deformities. (See chapter on exercise.)

Massage.—Massage combined with suitable exercise is the most readily available mechanical measure. Since arthritic joints are already a seat of an inflammatory process, it is a cardinal rule in arthritis that massage must be gentle and must be carried out in the neighborhood but not immediately over the affected joints. Some years ago in one of the author's hospitals an arthritic clinic was added to the existing traumatic clinic;

the first patients were admitted to the physical therapy department for "baking and massage," and the sturdy Swedish personnel started to treat them the way they did husky laborers with some local injury. Following that first massage treatment, practically every one of these arthritic patients was laid up for several days. The only massage movement permissible at times over an arthritic joint is the lightest form of stroking. There should be no twisting movement of the joint during massage; the patient should be encouraged to move the joints actively after application of heat and massage. When the help of a skilled technician is not available, the physician should give suitable instruction to family members for massage of a patient confined to the home; this will enable the patient to receive at least some massage with a measure of success. General body massage is of definite value for overcoming the feeling of fatigue, strengthening the muscular system, stimulating body metabolism and soothing the nervous system.

The application of any form of massage, local or general, should always be preceded by the application of heat, external or penetrating, for it opens the vascular channels, relaxes the parts and enlarges the range of motion. This is the reason for the effectiveness of the combination of heating and gentle massage or exercise enabled by the whirlpool bath and by underwater exercise.

Active motion must be insisted on in arthritis of the rheumatoid type if fibrous, and later bony, ankylosis is to be prevented. The safest way of carrying this out is to begin in subacute cases with muscle setting exercises (Chapter XXIX) and then start active exercises, first without weight-bearing and gradually extending them within the full possible range of motion after the parts have been limbered up by heat and massage. Manipulation of joints in conjunction with massage requires great caution. The patient must receive individualized instruction as to what exercises he can do at home and as to the range of motion he should attempt to attain.

General Exercise.—General exercise is invaluable toward effecting body correction in arthritis. Deep breathing and abdominal muscle control exert a beneficial effect on the circulation and functions of the body. For the restoration of function, the gradual use of these joints by corrective exercises and occupational therapy is much preferable to manipulation. In certain cases, exercise on simple apparatus may be useful.

Much of the disturbed physiological function in chronic arthritis can be ascribed to incorrect use of the body in faulty posture. Systematic corrective exercises and rest in the corrected position serve to remedy many of these physiological disturbances; therefore, from the very beginning of treatment of arthritis, correction of posture can help materially. Occupational therapy is invaluable for rehabilitating patients in all stages.

For visceroptosis and sluggish bowel activity of arthritic patients, exercise of the abdominal muscles by voluntary work or by a low tension wave current (the surging faradic or interrupted sinusoidal) may be indicated. Its systematic application aims to improve the tone of the musculature, peristalsis, venous return from the abdomen to the heart and also glandular function. Abdominal massage is also useful in such cases. Electric exercise of the large muscles of the extremities may aid in maintaining the tone and in preventing atrophy, so common in the later stages of arthritis.

Colonic Irrigation.—Colonic irrigation enables mechanical stimulation of the lower intestinal tract and combating colonic stasis by occasional thorough flushing and evacuation. Some clinicians consider the intestinal tract a major secondary focus of infection. Applied for definite indications and under responsible direction, colonic irrigation is a useful adjunct in treatment of arthritic patients in whom the gastro-intestinal tract appears to be the cause of some of the symptoms.

Thermal and Mechanical Measures.—The *whirlpool bath* by combination of heat and gentle friction softens inflammatory induration and relieves pain and spasm. It may be employed in chronic arthritis affecting several joints of an extremity, for weak and painful feet and in patients with additional myositic and neuritic involvement.

Underwater exercises, originally introduced for the treatment of paralysis, have proved to be quite effective in chronic arthritis for restoring joint function and muscular strength by well-directed exercise and manipulation. In the underwater treatment tank, joints can be put through a range of motion much beyond that achieved outside the water. As a matter of fact, there is danger of overdoing joint exercise in fairly tender joints. Often patients with badly affected hips, knees or ankles, unable to walk, gradually regain that function in the pool. Most patients prefer pool or tank treatments to gymnasium treatments because of the additional mental and physical stimulation. To be truly effective in advanced cases, underwater exercise needs expert guidance and sometimes special equipment for hoisting patients and placing them in the pools comfortably. However, in early cases the thoughtful physician can often devise suitable arrangements for such exercises in simple home surroundings.

Counterirritant Measures.—The *galvanic current* offers a useful adjunct in treatment of chronic arthritis, especially the atrophic type. It brings about prolonged hyperemia of the skin and has some effect on the deeper circulation by reflex or direct penetration. For therapeutic efficiency it is important that as large an amount of current as can be borne be applied for a sufficiently long time, at least a forty-five minute session. The *galvanic bath* offers a combination of mild general heating with the stimulating or "alterative" effect of the current to the skin. It serves as an alternate measure in institutional treatment and exerts no specific effects. Fragrant pine extracts or other resinous substances added to electric baths cause additional skin stimulation.

Ion transfer with vasodilating drugs is based on research work pointing to the close connection between the disturbed peripheral circulation and the arthritic conditions. These studies showed that in arthritis the capillaries of the skin have a tendency to remain empty and the flow of blood in them is sluggish. There is much less blood as a whole in fewer visible capillaries in many cases of arthritis than in normal persons. Histamine and choline compounds, when introduced by iontophoresis, penetrate the deeper layers of the skin and exert systemic as well as local effects; acting as antagonists to atropine, they stimulate the parasympathetic nerves and dilate the peripheral vascular system. Histamine ionization by the usual technique produces an intense local "counterirritant" effect. Mecholyl ionization produces a less intense local reaction, its effect amounting to a deposition of the drug in the deeper layers of the skin followed by gradual absorption. The physiological effects and technique of both procedures have been presented in Chapter VIII.

Mecholyl ionization has been found useful in rheumatoid arthritis when other methods directed to the relief of the local condition have failed. (Kovács, J. and R.,[9] Boyd *et al.*) Histamine ionization brings about a vigorous local reaction and is preferable in rheumatic myositis and neuritis; symptomatic relief in chronic and acute arthritides was reported by Reiley and Knapp.[15]

High-frequency treatment from the single high voltage or Oudin terminal of a spark-gap diathermy apparatus (Chapter XI) may give marked relief in cases of diffuse pains of neuritic character and of fairly subacute arthritis involving several joints. It should be given following external heating.

Ultraviolet Radiation.—Ultraviolet radiation from a mercury vapor lamp or cold quartz type of lamp furnishes relatively cold radiation, *i. e.,* with elimination of infrared rays. These rays will cause various degrees of the familiar sunburn (erythema). Applied over a painful joint, such a sunburn often acts as a counterirritant and alterative; hence the instinctive desire of many arthritics to expose their painful joints to the sun. Cautious local use of artificial radiation from the sources mentioned may serve as an adjunct or alternate to other physical treatment and should be repeated only after the previous reaction has subsided. Sunburning doses should only be applied to one region and not to the entire body.

Thermal and Counterirritant Measures.—*Natural sunlight* or artificial radiation from a carbon arc lamp represents a combination of infrared and ultraviolet radiation. When applied for general body irradiation in suberythemal doses, it serves as an aid in the constitutional treatment of asthenic arthritics, especially those of the rheumatoid type. The beneficial effects of light therapy are partly attributable to the general tonic effect of ultraviolet irradiation, partly to the thermal effect of the infrared component and perhaps also to the increase of the defensive power of the body by the products of biochemical changes in the skin and their effect through the circulation.

Spa Treatment.—A spa is a health resort developed around a mineral spring or springs which makes curative use of the water in conjunction with other natural resources and physical treatment agencies, such as climate, rest, exercise, and diet. The hot springs of the continent of Europe were the Meccas of rheumatic sufferers for many centuries and much of the gradually developed system of spa treatment was built around the treatment of these patients. It is evident that the general systemic debility, the vascular changes, the disturbed metabolism, the improper living habits and surroundings, as well as the painful inflammatory conditions of joints and soft tissues can be particularly well benefited by the combination of therapeutic factors, which well organized and medically well controlled spa treatment can offer.

The position of a modern health resort is midway between the home and hospital. It is not a diagnostic clinic or a research institution but a place for such patients who will be benefited by a combination of physical treatment, climate, diet and psychotherapy. Such a combination is most suitable for many cases of rheumatism and is the reason why most of the health resorts emphasize that they are treating arthritis and rheumatic conditions. Some of these even profess to specialize in the handling of such conditions. It is, however, evident that not all types of rheumatism will respond to spa treatment and that there exists no spa treatment method which exerts a specific curative effect on rheumatism. Unless the principal factors pertaining to the success of a health resort are available, the reliance of emphasis on any single therapeutic agent does not justify the sending of a patient to a distant spa. The presence of an ideal climate and a well equipped hydrotherapeutic department is not sufficient unless the patient gets the benefit of competent medical direction and trained technical assistance. He must also receive suitable hotel accommodations and appropriate diet, and the general atmosphere of the resort must be conducive to rest and relaxation. All of this must be available within the financial means of the rheumatic sufferer.

So far as the selection of types of rheumatism suitable for spa treatment is concerned, it appears to be a consensus that patients in the active stage of the rheumatic disease, especially rheumatoid arthritis, do better at home or at an institution at prolonged rest. In these cases, the exertion of taking treatments in a spa would far outweigh the possible benefit derived therefrom. After the acute stage, rheumatoid cases may be sent to a warm, dry region, where in addition to suitable rest, heliotherapy and diet, balneo- and hydrotherapeutic measures may be carefully applied. The application of too much heat must be avoided at all times.

Osteo-arthritis cases are generally more suitable for spa treatment. They are usually patients past middle age, often overfed and obese who have varying degrees of arthritic changes in some of their weight-bearing joints. They cannot change their mode of living or the abuse of their joints in their home surroundings. Such patients often do exceedingly well by "taking the cure" consisting of thermal measures, massage, judiciously restricted exercise, suitable diet and rest from business worrying or nagging relatives. In addition, any existing strain on the heart and the general circulation can be beneficially influenced and after a sojourn of several weeks these patients return home literally rejuvenated. No wonder that patients of this type return faithfully to their favorite spa for a renewal of the spa régime and keep comfortable, although the roentgen-ray pictures of their joints show the usual slow progress of the degenerative changes.

Similar considerations prevail in the employment of spa treatment in the treatment of cases of soft tissue rheumatism, chronic myositis, fibrositis, brachial neuritis and sciatica which have proven resistant to treatment at home. Long standing cases of traumatic, metabolic and gouty arthritis may also be considerably benefited by intelligently applied spa therapy.

Scheme of Physical Treatment

The large number of physical measures described constitutes an invaluable aid in the treatment of chronic arthritis and allows a selection of physical agents to fit almost every type or stage of the disease. It is evident that all these measures must be used in conjunction with a plan of general medical treatment. Some of the treatment measures are strictly institutional procedures, but most of them can be applied in the physician's offices and some may be carried out under skilled direction in the patient's home.

To be truly effective and safe, all forms of physical treatment must be used with the proper technique, including adequate dosage and length of each treatment. The frequency of application and the duration of a course of treatment must be regulated according to the severity of the condition and the patient's response. Because of the not too rare interplay of mental and physical distress in arthritis, spectacular results in some cases of long-standing pain or other symptoms are apt to signify primarily a relief of the superimposed nerve tension. Best success is achieved by a plan of painstaking, systematic use of treatment measures which take a long range view of the condition. Most patients will coöperate in this respect if the situation is frankly and fully explained to them. A note of optimism should always prevail; a cheerful outlook by both physician and patient is an important necessity in the treatment of chronic arthritis. Patients can be safely assured that in most cases there need be no fear of crippling and therefore that they should never become unduly worried when, despite treatment, attacks of pain return.

Taking into consideration the principal types and grades of chronic arthritis, the physical measures best suited for the average cases are as follows.

Osteo-arthritis.—In mild and moderate cases affecting one or two joints, radiant heat and massage or diathermy and massage should be used. In severe cases or in cases affecting several joints, a course of general heating measures is indicated; this may be done at times in the form of a cure at a spa. Exercises should be carried on regularly in all cases. In "worn out" joints, further wear and tear must be avoided by restriction of activities for a while and by suitable support by elastic bandages, caps or belts. On the other hand, in cases of advanced stiffness, suitable manipulation may help to restore motion.

Rheumatoid Arthritis.—Early cases require mild thermal treatment locally as well as systemically to aid general circulation. Acutely painful joints must have complete rest from the beginning. Early heliotherapy, natural or artificial, is important for general tonic effect. Suitable exercises, general as well as local, are to be instituted early to correct posture and prevent deformities. For local treatment, especially at home, daily use of luminous or infrared sources is advisable, followed by gentle massage and active exercise. Paraffin baths, whirlpool baths or ionization with vasodilating drugs are usually effective in reducing swelling and relieving pain in small joints which do not respond well to simple radiant heating.

Patients with advanced cases may receive cautious fever therapy if all other measures fail to cause enough response. Underwater exercises skilfully applied, systematic exercises to correct posture and support of weak joints are more essential here than in any other form of arthritis.

A few weeks' stay in a spa or health resort where suitable treatment measures are available under skilled medical direction is often eminently beneficial to many sufferers from both forms of chronic arthritis as already elaborated.

Gonorrheal Arthritis.—The specific effect of sulfa drugs on gonorrhea and its complications have to a great extent replaced fever therapy and local heat therapy in their former predominant rôle. However, there are patients who are hypersensitive to chemotherapy; there are also contra-indications such as liver and renal disease and the blood dyscrasias; finally there are cases in which drug therapy fails; consequently there is still a field for application of thermal measures, either alone or in combination with drug therapy.

Patients with acute gonorrheal arthritis must be kept in bed if a weight-bearing joint is involved; mild heating from radiant sources should be employed, preferably thermostatically controlled, at the degree most comfortable to the patient. Treatment to the focus of infection—the prostate and seminal vesicles, the female urethra and cervix has been successfully employed by Cumberbatch and his co-workers (for technique see Chapters XXX and XXXI). Cumberbatch emphasized the importance of treating the originally infected parts and at the same time of giving the diseased joint the benefit of local diathermy as well as that of other physical measures. In the chronic stage intense diathermy applied to the joints will clear up many cases.

Hyperthermy fulfils the indications for treating the focus of infection and the affected parts in one full swoop.

There is some difference of opinion as to the height and duration of fever treatment in gonorrheal arthritis. Solomon and Stecher[20] report complete relief in 52 per cent and marked improvement in 30 per cent of their cases with fever between 106° and 107° F. maintained from five to seven hours and repeated when necessary after intervals of two to seven days. The author has produced a similar average of good results in a series of 20 cases with temperatures between 105° and 106° F., maintained for an average of five hours. The relief of pain and return of function in some of these cases after even one fever treatment seems at times almost dramatic. Krusen[10] believes that one very long, very high session of fever, ten hours at 106.8°, is the most effective.

In the combination treatment by sulfanilamide and fever, as developed at the Mayo Clinic, the patient is given 80 grains of sulfanilamide each day for two days; this produces a concentration of 8 to 9 mg. of the drug per 100 cc. of blood. With this high concentration of sulfanilamide in the blood, a ten-hour fever treatment is given on the third day. With this procedure Krusen has found apparent remission of all symptoms and negative cultures in 96.2 per cent patients who did not respond to sulfanilamide.

In chronic cases of gonorrheal arthritis the management of residual pain, swelling, adhesions and limitation of motion often greatly taxes the endurance and skill of the physical therapist. It requires treatment along the lines already described.

Spondylitis Deformans (Marie-Strümpell Disease).—This is a painful stiffness of the spine caused by either atrophic or hypertrophic arthritic changes, ossification of ligaments, atrophic changes in the intervertebral discs or productive arthritis (osteophytes) with disintegration of the cartilage. An intensive course of general thermal measures, such as artificial fever or long applications of diathermy to the spine, is indicated in all grades, combined with suitable support to the back and careful active exercises. Suitable posture in bed with stretching of the spine is essential to prevent stiffening and kyphosis. A simple procedure is to place the patient on a flat surface, with a small soft cushion under the head, allowing sinking of the head and gentle stretching of the spinal column, beginning at five to ten minutes and increasing with a few minutes daily. Respiratory exercises are useful to increase chest expansion. Underwater treatment is frequently helpful. Abroad, galvanic full baths with the addition of vegetable extracts (Stanger bath) have been extolled. Good results from local ion transfer with a solution containing 1 per cent nupercaine and 70 per cent alcohol and 1 to 5000 epinephrine have been reported by Harpuder.[6]

Gouty Arthritis.—Typical attacks of this condition appear in overweight men after the age of forty with a sudden onset, usually caused by extreme pain and purplish-red swelling of the metatarsophalangeal joint of the big toe and adjacent parts. After keeping the patient miserable for a few days there is complete recovery and only after repeated attacks do bony changes and typical uric acid deposits known as tophi occur. Physical treatment in the acute stage consists of absolute bed rest, and possibly also a posterior splint holding the joint immobile; mild heating by warm compresses or still better a thermostatically controlled heating hood. Some patients do better under cold applications. In the chronic stage more intense local heating serves to absorb exudation and prevent residual fibrosis (Solomon and Stecher[21]); also electric cabinet or other baths may be used to secure diaphoresis and elimination of waste products.

Acute Arthritides.—In acute non-specific arthritis, as well as in acute rheumatic fever with active endocarditis favorable results with fever therapy have been reported by Stecher and Solomon[22] as well as Simmons.[17] In the now more frequently recognized joint manifestations of brucellosis (undulant fever) fever therapy has also been found effective. (Simpson,[18] Phalen *et al.*[14])

Tuberculous Arthritis.—This condition is being presented in Chapter XXIX.

Traumatic Arthritis.—This condition is also discussed in Chapter XXIX.

FIBROSITIS

Pathology.—It is now the generally accepted view that the "rheumatic syndrome" includes a great many acute and chronic inflammations outside of the joints, in the muscles, tendons, bursæ and in the nerve sheaths. The common pathological change in all these conditions is an inflammation of the connective tissues of the body, and is known under the term of fibrositis. This term has found universal acceptance in England, but is only gradually so becoming recognized in the United States.

Fibrositis has been defined as the reaction of the fibrous supporting tissues of the body to extraneous poisons which may be bacterial or toxic, and occurs in persons who are constitutionally disposed to such a reaction. The reaction may be acute or chronic. Osler states that in acute cases there is a serous exudate into the affected parts, following which there may be proliferation of the fibrous tissue, which may extend between muscle fibers, causing stiffness and pain. The acute stage is characterized by extreme tenderness and severe pain, either constant or only on certain movements; the affection is entirely local and the constitutional disturbance is slight. Muscular spasm is a frequent accompanying feature of this stage; this may be so painful that the patient is quite unable to move. No wonder that acute lumbago, the most frequent form of acute muscular involvement is known in German under the fitting term of "Hexenschuss" which means "shot by a witch." In the acute attack the muscular spasm may produce an extremely tender lump which resembles the nodule to be described but which disappears spontaneously when the attack passes off.

If resolution is not obtained in acute cases, by insidious progress the exudate becomes organized in the form of a "*nodule,*" the typical pathological lesion of chronic fibrositis. The nodule is a round, oval or longitudinal mass of avascular scar tissue, differing from normal fibrous tissue in its poor blood supply, lack of elasticity and tendency to contract. These nodules can be located by the trained finger in palpating relaxed muscles

Fig. 296.—Common sites for fibrositic induration on posterior portion of body. (Courtesy of Dr. F. H. Krusen[11] and Archives of Physical Therapy, *X*-ray and Radium.)

or other fibrous structures and may or may not be tender; they are the characteristic evidence of the chronicity of the disease. They may become tender again if further toxins are deposited as a result of lowered local resistance such as may follow local chilling. The nodule may be considered as a tissue reaction to the circulating toxins and not to bacteria, because the latter are never found in it; it is histologically very similar to the bodies described in the myocardium by Aschoff. According to Thompson and Gordon[24] the fibrous tissue formed as a result of inflammatory reaction is of a lower order than the normal fibrous tissue supporting the various organs. Once formed, the fibrositic nodule tends to persist until dispersed by appropriate treatment. One of the essentials of treatment is to find the nodule and "rub it out."

Diagnosis and Classification.—The diagnosis of fibrositis is made on the basis of the following points: (1) Typical pain and stiffness, following either exposure to cold or to strain or coming on insidiously in a person with a rheumatic disposition. (2) Typical bands or nodules, often acutely tender. The structure to be examined must be relaxed as much as possible and the fingers are passed along with a deep, firm stroke. When a nodule is situated in muscle fibers, firm pressure on it will often induce a reflex contraction of the muscle. (3) Exclusion of other conditions which may give rise to similar symptoms, such as affections of bony structures, organic nervous disease, tumors of inner organs. Fibrositis is often associated with chronic arthritis.

Slocumb[19] states that patients with fibrositis usually appear to be in good physical condition, which is not so frequently the case in arthritis; in fibrositis there is no intra-articular hydrops and no muscular atrophy such as in arthritis, although there may be slight thickening of the capsule of the joint. On subsidence of the acute stage of fibrositis the function of the joints generally returns to normal, although occasionally fibrous contractures occur. The roentgenograms of the joints remain normal and the sedimentation rate of erythrocytes is normal or only slightly elevated. Finally, in contrast to the average case of arthritis, there is usually no loss of weight and no significant anemia.

The main varieties of fibrositis are, according to the Arthritis Committee of the British Medical Association:[16] (*a*) intramuscular, fascial and periarticular fibrositis and bursitis. The acute and chronic muscular rheumatism are types in this group; (*b*) perineuritis, an involvement of the nerve sheath, especially in the brachial and lumbar plexuses, with the pain referred often down the course of the nerve. The large number of so-called neuritis cases without the typical sensory changes or trophic disturbances is explained by fibrous nodules often far removed from the localization of the pain; (*c*) panniculitis or fibrositis of the subcutaneous tissues.

Treatment.—The principles for the treatment of chronic arthritis are applicable to the treatment of fibrositis; general treatment must remove the cause and counteract the constitutional factors while local treatment aims to relieve pain and stiffness and to remove the cause of local symptoms, the nodule. Indeed, the treatment of the chronic condition is generally more effective because of the possibility to employ efficient physical measures for the resorption of the inflammatory thickening. Only the general principles of treatment will be enumerated here.

(*a*) Relief of pain and stiffness in the acute stage. The severe local pain in the acute stages of fibrositis overshadows all other symptoms. The patients instinctively seek to immobilize the affected part and physiological rest is indeed the most indispensable physical measure next to local heat application for the relief of pain. Immobilization should be provided by whatever mechanical means are best suited for a given location: firm bandaging, strapping, wearing of a sling; or complete rest in bed. Heat is administered by exposure to luminous heat or infrared radiation in efficient dosage. Diathermy is as a rule well tolerated in the acute stage of myositis, but not so well tolerated in neuritic affections. Ultraviolet radiation is definitely contraindicated in this stage. The use of sedative medication for a day or two is often indispensable, especially in order to insure rest during the night.

(*b*) Constitutional treatment: removal of underlying causes and preventing of recurrence. Constitutional treatment should be instituted at the earliest possible moment, *i. e.*, as soon as the acute symptoms have subsided and the probable cause of the condition has been ascertained. It should be planned on the lines of attack outlined for chronic arthritis with the difference however that especial emphasis must be laid from the outset to locate and eradicate possible foci of toxins circulating in the system, as may exist in the form of dental abscesses, dead teeth, infected tonsils, disturbances in the absorption or elimination from the gastro-intestinal tract.

An equally important phase of the constitutional treatment is the increase of elimination through the skin and the raising of general metabolism. Nothing fulfils this object so satisfactorily as a systematic course of general thermal measures—as outlined in the first part of this chapter. Clinical experience has shown that in the vast majority of cases patients respond with definite improvement in their general as well as in their local condition to such a course of treatment, provided it is selected and carried on in accordance with the tolerance of the individual. Systematic muscular exercise, "hardening" of the skin against chilling by suitable hydrotherapeutic procedures should also be employed if indicated. It is the instinctive desire of the rheumatic sufferer for a general regimen of elimination, relaxation and upbuilding, which fills many of the health resorts. Many of the beneficial effects of a well directed "cure" can be provided, however, in home surroundings and in physicians' offices by comparatively simple means. As an all year round prophylaxis against the recurrence of the disabling and painful attacks in the various forms of fibrositis, a continued constitutional therapy is of paramount importance.

The local treatment of fibrositis in its diverse manifestations will be discussed under the heading of neuritis in Chapter XXVIII and under bursitis and myositis in Chapter XXIX.

The specific treatment for the fibrositic nodule recommended by practically all clinicians is manipulative treatment, *i. e.*, actual breaking up and dispersal by heavy local massage. Ordinary massage over an entire extremity is useless according to Mennell,[12] whereas concentration over the affected regions, deep thumbing movements, deep kneading and upward pressure seems actually to break up the deposits and relieve the muscular pain. Krusen[11] confirms the occasional disappearance of nodules under special heavy massage, but also reports frequent recurrences. The author believes that with well directed heavy static sparks he has accomplished similar results; Smart extols the use of the faradic current for the same purpose.

Panniculitis.—This is a condition which most frequently occurs in middle-aged women and is characterized by an atrophy of the skin in circumscribed spots, due to a subcutaneous fibrositis. The affected areas are extremely tender and show a characteristic mottled dimpled appearance. This tenderness is best demonstrated by attempting to pick up the skin between the finger and the thumb. The normal elasticity of tissues shows great diminution and there is often a cyanotic change due to venous congestion.

Patients are usually of an obese type, complain of peculiar aches and soreness in various parts of the body, are easily fatigued and nearly always constipated.

Treatment.—Treatment along the general lines for fibrositis usually gives satisfactory results. Small doses of thyroid extract are helpful; this proves that the disease is connected with some endocrine dysfunction, thus resembling Dercum's disease or adiposis dolorosa.

Results of Physical Therapy in Rheumatic Disease.—The earlier in the disease physical measures are instituted the more satisfactory are the results as reported by Glover,[5] Pemberton,[13] Wyatt[26] and the British Red Cross Clinic for Rheumatism.[8] The Red Cross Clinic treats patients by all recognized methods but places special emphasis on physical treatment; it reports that of 2314 patients discharged in 1935 with treatment completed, 51 per cent were cured or free from symptoms, 35 per cent definitely improved, 13 per cent unchanged or only slightly improved and less than 1 per cent worse.

These reports of competent observers further corroborate the now generally accepted conception that to a great extent the rheumatic group of diseases, including chronic arthritis, is both preventable and curable. It is essential, therefore, that the pessimism resulting in the inactivity of yesteryears be replaced by a well-founded optimism. However such optimism must be based on the medical man's correct diagnostic capacity as well as his ability to select from all established methods of treatment those most likely to benefit the individual patient. Physical measures should play a large rôle in the treatment of all forms of chronic arthritis.

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CHAPTER XXVII

AFFECTIONS OF THE CENTRAL NERVOUS SYSTEM

General Considerations. Hemiplegia. General Paresis. Poliomyelitis. Locomotor Ataxia, Multiple Sclerosis, Myelitis. Chorea Minor. Cerebral Palsy. Obstetric Paralysis. Infantile Paralysis. The Neuroses. Mental Conditions. Electric Shock Therapy.

General Considerations.—The evolution of the application of physical energies for the treatment of nervous and mental diseases represents a change from crude superstition and empirical therapy into well controlled clinical methods resting on a rational theoretical and experimental basis. For many centuries, sufferers from mental disease were supposed to be "possessed" by Satan and were subjected to cruel physical restraint, being kept in chains with thieves and murderers. About one hundred and fifty years ago Pinel took off the fetters of mental patients at the Saltpetriere in Paris and espoused the use of hydrotherapy for its sedative and tonic effect on mental illness. Gradually other forms of physical treatment were introduced, especially electricity, but at first without either rhyme or reason. In Haynes' text-book on electrotherapeutics printed thirty-five years ago one can still read such statements as, "It is believed that the galvanic current penetrates the substance of the brain while the faradic current is distributed chiefly to the membranes," also "This rule has been given for the use of galvanism in insanity; recent cases and functional diseases are benefited by it while old cases and structural diseases resist its influence." No wonder that well known neurologists recommended the use of electricity more or less in the form of a placebo or as a convenient means of disguising suggestive therapeutics and gave blanket recommendations for its use without specifying its form and without any reference to technique.

Modern progress in physical therapy has given us a definite conception of the mode of action of physical energies in affections of the central nervous system and their limitations. No form of physical therapy can be expected to restore highly differentiated elements of the central nervous system once they have been destroyed, but it is a fact that many of the pathological changes in the nervous system are subject to restitution. Table 53 indicates changes in the nervous system and the problems of treatment.

All physical measures exert a certain amount of psychic effect partly by tonic action and partly in the form of suggestive therapy. Hence they offer a valuable therapeutic aid in psychoses and psychoneuroses. It is a frequent experience in mental hospitals that the mental status of patients shows improvement while they receive physical treatment for a non-mental condition such as traumatism or arthritis.

Neurosurgeons and orthopedic surgeons have learned to appreciate the value of currents of low tension and low frequency in the treatment of muscular weakness and paralysis. Underwater exercises enable a new form of treatment of infantile paralysis and have been also extended to the treatment of the after effects of hemiplegia and cerebral palsy. The various forms of hydrotherapy form today an indispensable part of the routine treatment in mental institutions.

TABLE 53.—CHANGES IN NERVOUS SYSTEM AND PROBLEMS OF TREATMENT (AFTER VERAGUTH[36])

I. *Changes of possible reversibility*	I. *Treatment to facilitate*
(*a*) Disturbances of optimal excitability	(*a*) Return of optimal excitability
1. In vegetative nervous system	1. } Physical, medicinal and dietetic therapy
2. In sensomotor part	2. }
3. In substratum of higher psyche	3. Principally by psychotherapy
(*b*) Toxemia	(*b*) Detoxication
(*c*) Inflammation	(*c*) Resorption
(*d*) Destruction of neurons capable of regeneration	(*d*) Regeneration
II. *Threatening or absolute irreversibility*	II. *Treatment to retard progress*
Destruction of neurons through { Toxemia; Inflammation; Anomalies of circulation; Mechanical force; Foci causing pressure	{ Physical, medicinal, diet therapy; Possibly through surgery; Possibly through *X*-ray therapy

III. *Treatment in all cases*
Improve function of intact part of nervous system
Care of connective organs

TABLE 54.—CONNECTION BETWEEN PATHOLOGICAL STATES OF THE MOTOR TRACT AND MUSCLES AND THEIR ELECTRODIAGNOSTIC SYMPTOMS (AFTER POTTS)

Seat of lesion or disease	Electrical reactions
1. Brain cortex and the pyramidal tracts: cerebral apoplexy and the resultant paralysis; tumor; abscess; transverse or compression myelitis (muscles supplied by nerves arising from segments below the seat of the lesion); lateral sclerosis; hysterical paralysis.	Normal usually; if paralysis is of long duration, sometimes slight diminution of excitability.
Pyramidal tracts and the cells of the anterior horns of the cord (central and peripheral neurons). Amyotrophic lateral sclerosis.	In non-atrophied muscles, normal; in atrophied muscle either quantitative decrease or RD (usually partial).
2. Cells of the anterior horns of the cord and bulbar motor nuclei (peripheral neuron)	
(*a*) Acute poliomyelitis; transverse myelitis, tumor hemorrhage, localized meningitis, syringomyelia (muscles supplied by nerves from the affected segments when the gray matter of the cord is involved) and glossolabiolaryngeal paralysis.	(*a*) Various degrees of RD; in acute poliomyelitis most often complete.
(*b*) Progressive muscular atrophy	(*b*) Quantitative decrease in early stages. Various degrees of RD in the later. This may also apply to syringomyelia, localized meningitis and glossolabiolaryngeal paralysis.
(*c*) Myasthenia gravis.	(*c*) Myasthenic reaction.
3. Peripheral nerves (peripheral neuron): neuritis from various causes, as rheumatic, traumatic or toxic; progressive neuritic muscular atrophy	Quantitative decrease in mild cases. Various degrees of RD in the more severe ones.
4. Muscles.	
(*a*) Myopathies or dystrophies	(*a*) Normal or quantitative decrease.
(*b*) Myotonia congenita	(*b*) Myotonic reaction.
(*c*) Tetany	(*c*) Quantitative increase.

Electrodiagnosis has been recognized for many years as invaluable in amplifying or corroborating clinical findings or in affording the means of important differential diagnosis between organic (central and peripheral) and functional or hysterical paralyses. It is an important help in prognosis and forms the basis for the selection of the effective form of electrotherapy in lesions of the central and peripheral nervous system as shown in Chapters VI and VII. Testing by condenser discharges, by determination of the chronaxie and by electromyography has added newer methods of great accuracy.

For the determination of appropriate therapy in affections of the motor tract the differentiation of paralysis according to the site of the lesion is important. The upper motor tract extends from the psychomotor cells in the brain to the terminal arborization of the pyramidal tract in the anterior horns of the spinal cord, while the lower motor tract extends from the ganglion cells in the anterior horns through the motor root and the peripheral motor nerve to the end-plate in the muscle fibers. (Fig. 80.) A lesion in any part of this long path may produce paralysis. The essential difference between the two types is that in upper motor neuron lesions the trophic center of the muscle in the spinal cord remains unimpaired and no denervation of muscle follows, whereas in those of the lower motor neuron muscular atrophy or a reaction of degeneration eventually occurs.

In lesions of the central neuron electrical stimulation of muscles has little clinical value, whereas in those of the lower motor tract it has become an indispensable part of routine treatment for the maintenance of muscular function, improvement of nutrition and in some cases for acceleration of the return of function.

Hemiplegia.—The term hemiplegia signifies paralysis of one side of the body. It is the result of a primary lesion in the cardiovascular system. Hemiplegia is brought about by one of two causes: (1) Arterial obstruction with resultant softening of the brain due to embolism or thrombosis. (2) Arterial hemorrhage; this is less frequent than thrombosis, but more often fatal. Intracerebral hemorrhage is caused by the combination of the degeneration of the arterial wall and high blood-pressure.

The manifestations of an attack of hemiplegia is the apoplectic stroke which usually comes on suddenly and is accompanied by focal signs which reflect the loss of function of the affected parts of the brain. As a result there remains a distressing train of symptoms that may include disturbances of speech, of gait, of the movements of the arm and hand and often mental lassitude, dizziness and loss of memory. Most of these symptoms have the tendency to recover spontaneously. The extreme limit of spontaneous restitution ends between the ninth to twelfth month.

Physical therapy has a definite place in this condition for the early rehabilitation and re-education of affected extremities, hastening convalescence and restitution and contributing to mental ease. The physical therapist as a rule does not see many cases of hemiplegia in the acute stage except in general hospitals. Early treatment gives the patient a better chance of recovery; the final result depends on the extent of the subsequent recovery of the affected motor areas. In the *first week* of hemiplegia while the patient may be still in bed, the application of radiant heat to the affected arm or leg will comfort and tend to relax the paralyzed limbs. Faulty positions of the joints with subsequent contractures are prevented by simple splinting and frequent changes in the position. Passive movements should be performed early and be accompanied by gentle stroking massage. As soon as some muscular power has returned the patient should be encouraged to do active exercise, thus counteracting the tendency to contracture.

In the *subacute stage* physical treatment may be instituted in two directions. One is for accelerating the circulation in the brain. Cerebral galvanism, transcerebral calcium iontophoresis and diathermy have been employed for this purpose. The technique of cerebral galvanism has been described in Chapter VIII. The author has seen frequent benefit from this treatment in patients in the subacute stage complaining of headache and dizziness—not due to persistence of high blood-pressure. Whether the favorable results are due to a direct influence upon the pathology or to reflex stimulation from the periphery, is undetermined. Treatment by skilled hands is perfectly safe and pleasant and can be administered at the bedside. It should be applied daily at first, later every other day and continued for several weeks, depending upon the response.

Cerebral diathermy has been reported on by Martucci *et al.*[22] With treatment administered three times a week for twenty minutes to one hour these authors have produced considerable relief and explain their results by reflex acceleration of the circulation. French authors have reported a favorable influence on contractures, gait and speech by short-wave diathermy to the brain.

Calcium ion transfer (Chapter VIII) has been extolled by Bourguignon and Cross[8] for old cases of hemiplegia, recommending treatment of thirty minutes' duration at a current strength from 2 to 4 milliamperes. This is to be carried on daily for six days and subsequently on alternate days for three weeks. A three week rest period should follow the month's active treatment; and they assert that definite improvement is usually manifest by this time.

A further important object of physical treatment is the improvement of the vasomotor and sensory disturbances and the spastic paralysis. Early gentle massage may help greatly in relaxing spasticity and restoring normal motion. Suitable manipulation and active exercise may be combined with graduated electric muscle stimulation. The application of radiant heat always should precede such treatments.

Electrical stimulation of the paralyzed muscles by a suitable surging current may begin after a few weeks. The dispersive large pad electrode, well moistened, is placed under the cervical or lumbar spine, according to whether the upper or the lower extremity is treated. The active electrode, a small disc, $1\frac{1}{2}$ inches in diameter, covered with gauze, is placed in turn over each motor point. Current at sufficient intensity is used to cause a few gentle contractions in each muscle. Such treatment requires patience and perseverence. It may be time-saving to mark the motor points on the skin with an indelible pencil to help to locate them at subsequent treatments.

A simple method of group stimulation is that through the medium of a water-bath. The hand or foot of the affected side is placed in a basin or other container with warm water, and the two terminals of the apparatus are connected to metal strips laid in the water. Just enough current is used to cause a faint visible muscular response at a rate of about thirty contractions per minute. This is kept up for five to twenty minutes and repeated every other day. This technique stimulates primarily the normal muscles and only secondarily those which are out of control.

The value of electrical treatment is doubted by those who feel that spastic muscles are only too prone to respond to any stimulus; it is recommended, therefore, that electrical treatment should be applied to the opposing normal muscles in order to prevent their overstretching. Most observers agree that this is rather far-fetched and that gentle electric exercise tends to relax and contract the spastic muscles and serves to maintain nutrition during the process of recovery. Occupational therapy is important in keeping up the patient's morale and serves, too, as a stimulus for active exercise.

Underwater exercises in a tank or pool have been successfully employed in recent years to relax spastic muscles in hemiplegia and to encourage voluntary use. Hydromassage of the affected limbs by a whirlpool bath is an efficient combination of heating and massage.

For paresthesias and other painful sensations the monoterminal high-frequency (Oudin) current may be applied advantageously. The glass condenser electrode is rapidly moved over the well-powdered skin and is held in close contact to the parts. (Fig. 183.) The current is regulated so as to cause just a gentle pricking and mild surface warming.

General Paresis.—Artificial fever therapy has opened up a new vista in the treatment of this formerly so resistant affection. Neymann[26] states that intense and prolonged treatment with electropyrexia offers a decided hope of recovery to every early case of general paresis and that the extent of psychotic manifestations has no bearing on the question of recovery. All observers found most favorable clinical and serological results in those paretics who received fever therapy followed by intense chemotherapy.

Ewalt and Ebaugh[10] in a five-year study found 69 per cent remission in a group treated with fever and 58 per cent remission in that treated with malaria. They hold that an important asset of fever therapy is that the patient may be safely treated at higher levels of temperature than is possible with therapeutic malaria. The patient also usually gains weight and is in better physical condition, whereas malaria therapy causes loss of weight and some degree of anemia. Results were good in the mild cases of both groups and less satisfactory in severe cases. Intensive follow-up chemotherapy is essential to obtain optimal sustained results.

In applying fever treatment to cases with cerebrospinal lues it is important that sessions of sufficient intensity and frequency be given. Temperatures below 103° to 105° F. have little clinical value in any type of syphilis. In the series of Ewalt and Ebaugh treatments at 105.8° F. were administered for three hours for twelve sessions. Simultaneous chemotherapy was given, which is not possible when administering malaria treatment.

In serologically fast syphilitics the use of ultraviolet irradiation, combined with autohemotherapy—injections of progressive amounts of the patient's own blood—was proposed by Rajka and Radnai.[32] Liberman and Spark[20] claim that by using gradually increasing erythema doses of ultraviolet in addition to chemotherapy in dementia paralytica, patients improved more rapidly.

Locomotor Ataxia.—It is to be expected that in a trying condition like locomotor ataxia various forms of electricity should be employed symptomatically in an effort to stimulate function and relieve pain.

Diathermy has proved beneficial for the relief of lancinating gastric, bladder and leg pains. It may be applied either through the spine or to the spine and the site of the lancinating pains. In employing diathermy it must be remembered that the sense of temperature is often impaired in locomotor ataxia. The current strength must be kept well within the toleration calculated according to the size and relative position of electrodes.

Galvanism has been advocated in the form of galvanic baths and by direct application to the spine, at 20 to 30 milliamperes for twenty to thirty minutes. No definite reports on the results of this treatment have been made. The static wave current applied to the spine and followed by static sparks to the spine and lower extremities has been employed by the author and other clinicians for improving the paresthesias and the general strength. It should be preceded by radiant heating or diathermy along the spine.

Artificial fever therapy has been employed in recent years with similar technique as in dementia paralytica. It is recommended that fever treatment should be used mainly in progressive cases which appear clinically and biologically resistant to the usual specific treatment; it appears useful in relieving tabetic pains especially in those cases which are characterized by repeated shooting pains or gastric crises; it is also recommended in tabetic optic atrophy. A series of 10 treatments two or three times a week with a temperature a little above 105° F., applied for four to six hours is advised. The degree of improvement possible depends mainly on the extent of pathological changes in the cord prior to treatment and is, therefore, not predictable. A tabulation by Neymann[25] of cases treated with fever therapy shows improvement in 54 to 60 per cent. The author has had some encouraging results with fever therapy in early cases.

Multiple Sclerosis.—Artificial fever treatment of this inflammatory affection of the spinal cord of uncertain origin, so resistant to various lines of treatment has been employed in recent years. The conclusions as to results are somewhat divergent, chiefly because the number of cases in each series was too small and therefore not classified. Bennett and Lewis[3] reported 51 cases of multiple sclerosis treated by artificial fever and followed up for an average of thirty-one months. These cases were evaluated on the basis of the following comprehensive classification: (1) early cases—10 patients could walk without assistance when admitted for treatment, did not need hospitalization and their symptoms did not date back longer than one year; (2) intermediate cases—25 patients required some form of assistance to be ambulatory, were unable to work and were almost completely disabled because of cerebellar and pyramidal tract involvement; (3) advanced cases—16 patients were either bedridden or needed wheel chairs and their symptoms were of long duration. No patient was included who had not received at least four treatments. Most of them received 6 treatments, each of three or four hours at 104° F.

These authors conclude that fever therapy should be tried in the early cases for the results seem better than might be expected without treatment. In the intermediate types, the benefits are doubtful; therefore, other less vigorous methods are indicated. In the bedridden group, fever therapy does no good and may do harm.

Before the advent of fever therapy, diathermy to the spine was favored by some neurologists in the spinal type of the disease. Improvement in the sensory fields was noted within twenty-four to forty-eight hours after the first treatment. Improvement of the spastic syndromes after short-wave diathermy to the spine was reported by Walthard.[37]

Myelitis.—Treatment calls for restoration of function. Weisenburg and Alpers[38] state that physical treatments in myelitis must be carried out over a prolonged period, and it is surprising how persistence will be rewarded often by encouraging results.

In paraplegia gentle muscular electrical exercise is useful in stimulating the muscular function. A large dispersive electrode is placed over the spinal column well above the site of the lesion and connected to one pole; two smaller electrodes are placed under the soles of the feet and connected to the other pole. On alternate days only the two foot electrodes may be employed, each connected to one pole. Each leg may also be treated separately, with a longitudinal technique. The patient is encouraged to do active work with the affected muscle groups. The improvement depends on the extent of the lesion.

Decubitus or bed-sores do well under irradiation from a luminous heat lamp followed by local ultraviolet treatment.

Chorea Minor.—Striking results by fever therapy have been produced in this condition regardless as to whether its etiology was infectious or psychogenic. Treatment of children in heat cabinets or by electromagnetic fever induction has proved safe and practical.

Sutton and Dodge[35] used temperatures between 105° and 106° F. for four to five hours and found that it was possible to cut short an attack of chorea with 1 or 2 treatments, especially when cases are treated early, regardless of the severity of the disease. Carditis is no contraindication to treatment and, according to Sutton and Dodge, fever therapy may be a valuable measure in rheumatic carditis. Barnacle *et al.*,[2] in a series of 45 cases treated at temperatures ranging from 105° to 105.4° F. with short daily sessions of only two and one-half hours' duration achieved similar excellent results with an average of 12.6 treatments of a total duration of 32.9 hours. There were only four recurrences. Finally, Osborne *et al.*[28] treated 25 patients with chorea minor, 7 of whom presented some degree of carditis. The electrocardiograms of some of the patients showed striking improvement. These observers concluded that artificial fever ranging up to 107.6° F. sustained for five to eight hours does not adversely affect the heart or the cardiovascular system if the doses of fever are those normally employed for treatment of disease.

Cerebral Palsy (Spastic Paralysis).—In this common affection of infants and children the essential pathological change is the destruction of the upper motor neurons resulting in disturbance of the voluntary motor function. The most frequent cause is intracranial hemorrhage resulting from trauma at birth; however it may be also due to arrested development before birth and to infections or traumatic lesions after birth (encephalitis, meningitis, etc.).

The treatment of the characteristic spastic symptom complex is essentially a process of rehabilitation, embracing a long program of muscle training. It must be adapted to the two types of spastic paralysis; spasticity and athetosis. (1) In *spasticity* there is injury to the cortex of the brain and if the hemorrhage affects the intelligence area, the child's mentality is impaired. The spastic muscle is thrown into maximal contraction at the least stimulus especially by the stretch brought about by any movement of its antagonist. This results in difficult and inaccurate voluntary movements and in an increased muscular resistance to passive manipulation. The spastic patient is to be treated by careful exercise, avoiding stretch reflex. The spastic muscles must be taught to relax voluntarily to the stimulus that would ordinarily cause them to contract. Still more important is exercise of the weakened antagonist. Surgery upon the brain, nerve roots, muscles and tendons may be done in some cases to diminish muscle spasm, equalize the power of opposing muscles, or correct deformity. (2) *Athetosis* is due to an injury to the basal ganglia or extra-pyramidal tracts; it is characterized by more or less constant involuntary contraction of successive muscles, which becomes superimposed upon voluntary movements and results in marked incoördination. The muscles of the athetoid are essentially normal and do not need any exercise to strengthen them; he needs to learn relaxation, so as to be able to move them with a minimum amount of tension and be able to control the force and direction of the desired act. Occupational therapy and vocational rehabilitation is the final step in training both types of cases for "total activities." (Phelps.[30])

Obstetrical Paralysis.—"Birth palsy" is due to mechanical injury of the nerve roots of the brachial plexus during prolonged and difficult birth, resulting in paralysis of the muscles of the upper extremity. There are three types of this lesion: (1) The upper arm or Erb-Duchenne type is due to injury of the fifth and sixth cervical trunks; it results in typical internal rotation and adduction of the shoulder, while the movements of the wrists and fingers are not affected. (2) The lower arm or Klumpke type, due to a lesion of the first dorsal and eighth cervical trunks; it affects the intrinsic muscles of the hand and sometimes the long flexors of the fingers. (3) The whole arm type. In all cases there is a flail or limp extremity; the infant will flinch or cry on passive motion of the injured arm and a painful neuritis is present for several weeks. The prognosis depends on the amount of injury varying from slight stretching to complete rupture and resulting in severe cases in cicatricial fibrosis.

The early treatment of this condition consists in suitable splinting, maintaining rest and taking tension off the torn fibers of the brachial plexus in a position favorable to healing. After subsidence of the neuritis the arm should be taken out of the splint several times a day for gentle massage and manipulation to prevent the development of contractures; this should include passive movements of all joints of the upper extremity. Metal braces or splints are used later to maintain the best position for the arm and as function gradually returns, the brace may be left off for gradually increasing periods during the day. Active and passive exercises should be continued for a long period and surgical help considered in cases which do not make satisfactory recovery. In postoperative care intelligent physical therapy again plays an important rôle.

Infantile Paralysis.—The pathology and the methods of treatment of anterior poliomyelitis or infantile paralysis received much study during recent years chiefly due to the interest created by Sister Kenny's work and as a result the rôle of physical therapy in early treatment has been much advanced.

The variety of changes occurring in the spinal cord following an attack of acute anterior poliomyelitis are described as follows (Hansson[14]):

(1) Round cell infiltration and transitory productive inflammation can

produce enough pressure on the anterior horn cells to inhibit their function temporarily. (2) Interference with the horn cells' nutrition may occur by surrounding hemorrhage or blocking of nutritional vessels. (3) The virus may injure the nerve cell without destroying it. (4) The nerve cell may be completely destroyed. When paralysis occurs during poliomyelitis one can make no estimate of this injury, but one has to deal with muscles presenting varying degrees of weakness. The degree of recovery depends upon the extent of the damage to the cells of the cord: those destroyed will not recover, but cells only injured by the virus or by inflammatory changes of the cord may recover and allow the nerve filaments to the muscles to regenerate. Early in infantile paralysis no prognosis can be given as to which muscles will recover and which ones will be permanently paralyzed: only time can determine this.

The three phases of infantile paralysis are: the acute, characterized by fever, tenderness and systemic disturbance; the convalescent, beginning with the disappearance of muscle soreness and characterized by the tendency of the paralyzed muscles to recover their tone and power; the chronic, in which spontaneous improvement can no longer be observed. Until very recently the generally established orthopedic management of acute cases consisted chiefly of strict immobilization of the affected parts, in order to lessen tenderness and prevent contractures. Although it was observed that during this period muscles undergo rapid wasting and there is extensive loss of function, physical treatment toward restoration of function was as a rule not started until all tenderness disappeared.

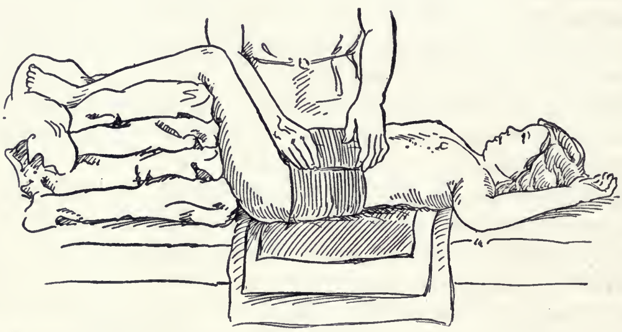

Fig. 297.—Hot fomentations for abdominal and low back "muscles in spasm"; flexion of thighs to relax psoas spasm. (Courtesy of Dr. Philip Lewin and Illinois Medical Journal.)

The newer concept of infantile paralysis holds that the disease not only affects the anterior horn cells but also adjacent portions of the cord and it may involve the central nervous system including the sympathetic system; furthermore, it causes extensive muscle spasm, which may be responsible for much of the functional disturbance and pain. Sister Kenny promulgated the three concepts of "muscle spasm," "incoördination," and "mental alienation" which result in shortening of the affected muscles, disorganized movement and loss of power in non-affected muscles. She advocated immediate physical treatment of spasm by hot "foments" with a painstaking technique, while keeping the patient at rest without formal splinting. (Fig. 297.) Re-education of muscles is started as soon as spasm permits; it consists of recreating an "awareness" in the patient's mind of the existence of the muscle and its proper function and is accomplished by fixing the patient's attention on the insertion of the "alienated" muscle followed by the gentlest passive motion. (Fig. 298.) As soon as the patient's condition warrants, carefully supervised active motion is undertaken. Sister Kenny claimed that patients treated by this method have complete freedom from all contractures, and there is no scoliosis or joint stiffness. Pain disappears quickly and respirators are not needed.

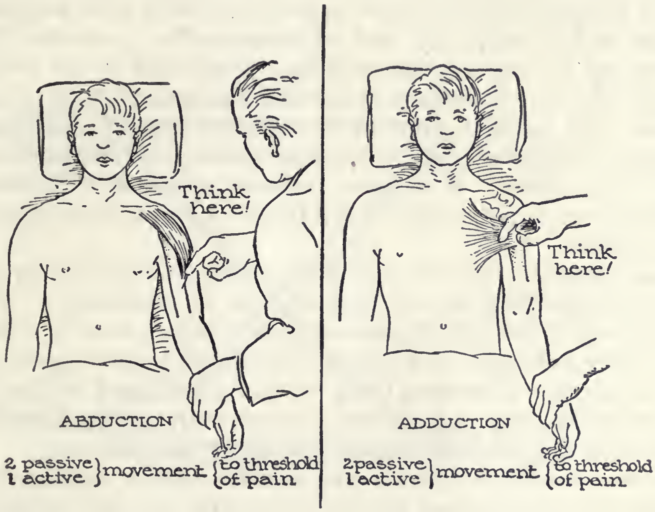

Fig. 298.—Muscle re-education: left for deltoid, right for pectoralis major. (Courtesy of Dr. Philip Lewin and Illinois Medical Journal.)

The extensive clinical and laboratory study stimulated by the interest awakened by the Kenny concept confirmed the existence of muscle spasm, chiefly in the antagonists of weakened muscles, but it also showed its presence in the weakened muscles themselves.[5] Neck muscles show spasticity in nearly all cases. It was also corroborated that the early judicious use of sedative-decongestive fomentations reduces muscular spasm, pain and tenderness so that careful assisted movement is possible without pain.[39] The early use of physical therapy prevents much of the muscle contracture and dysfunction following the method of rigid immobilization, and in the end-results the incidence of late deformity appears low and the incidence of functional ability is rather high. But there has been no acceptable proof offered anywhere that the incidence of residual paralysis has been changed to any extent; in other words the muscular units which have received permanent primary insult from the activity of the virus remain paralyzed under any form of presently known treatment.

A comprehensive plan of the present day treatment of infantile paralysis from the standpoint of the orthopedic surgeon has been presented by Compere:[6]

In the *acute stage:* (1) strict contact isolation and quarantine; (2) administration of convalescent serum immediately; (3) application of hot moist packs, changed every hour for twelve hours each day; (4) use of a respirator at the first indication of cyanosis or dyspnea, with continuation of hot packs, and (5) gentle passive motion of all extremities at least once a day. In the *subacute stage,* the following measures are employed: (1) cursory orthopedic examination with minimal manipulation; (2) careful positioning with a hard mattress and foot board; (3) hot packs to the hamstrings and spine of all patients with stiffness; (4) hot packs to the muscles of all extremities with tenderness or evidence of spasm; (5) administration of prostigmine bromide; (6) passive exercises with encouragement of active motion; (7) correction of incoördination and mental alienation by the Kenny method; (8) mobilization of the spine by extension of the knees in a sitting position; (9) free activity one hour each morning before application of hot packs and each afternoon after application, and (10) early attempts at standing and walking. Treatment in the *chronic stage* consists of: (1) use of braces and abdominal support according to individual indications; (2) surgical procedures, such as tendon transplants and arthrodeses, as indicated, and (3) frequent observation and maintenance of mobility of the spine. If scoliosis becomes apparent in a child whose longitudinal growth lies mostly in the future, a prophylactic spinal fusion may be in order.

Physical therapists have for a long time advocated early thermal treatment in infantile paralysis by radiant heat or diathermy. While the Kenny method of hot fomentations is undoubtedly effective it requires a relatively large number of technicians or nurses and much special material. It may be possible to replace them with a simpler and just as effective form of thermotherapy and develop a more definite estimate as to what extent and how long thermal applications are to be continued.

Underwater treatment of weakened muscles offers a desirable means to combine early heat treatment with careful muscle exercise. A recent report by Hipps and Crook[15] states that patients receiving early underwater treatment showed twice as much improvement as two sets of patients, one treated by early rest and immobilization, the other receiving no early treatment of any kind. For further details of underwater treatment see chapter on exercise.

From the standpoint of physical therapy it is fortunate that the great majority of muscles are weakened rather than paralyzed. Figure 299 shows schematically how a muscle is innervated by nerve fibers from various levels or segments of the spinal cord. Consequently in affection of the anterior horn cells at one level one muscle may still be innervated by fibers from an adjacent unaffected spinal segment. This explains the frequent occurrence of the retention of partial muscle power and the partial RD on electrical examination. It also increases the chances of recovery by strengthening the unaffected part of a muscle by suitable exercise.

Careful grading of muscle power should be made as early as possible to serve as a guide for suitable physical treatment and as a basis to judge progress.

At present three methods of muscle grading are available: (1) Clinical examination, tabulating muscles from zero, meaning no trace of power up to 50 per cent at which the muscle can complete the whole arc of motion of gravity, but may tire after two to three movements, while at 100 per cent the muscle is able to act against maximum resistance. This method must be carried through by one examiner because of the element of individual equation. (2) Electrodiagnosis as described in Chapter VII. Muscles without RD will recover spontaneously or the recovery will be speeded up by appropriate therapy; those with RD may show varying degrees of affection and should receive treatment as early as possible. This method is applicable only in older children. (3) Electromyographic testing by recording the action currents of muscles (Chapter VI) is the latest method; it is exact, but it requires complicated equipment.

For the grading of spasm functionally, a comprehensive scheme was described by McFarland and Graves.[23]

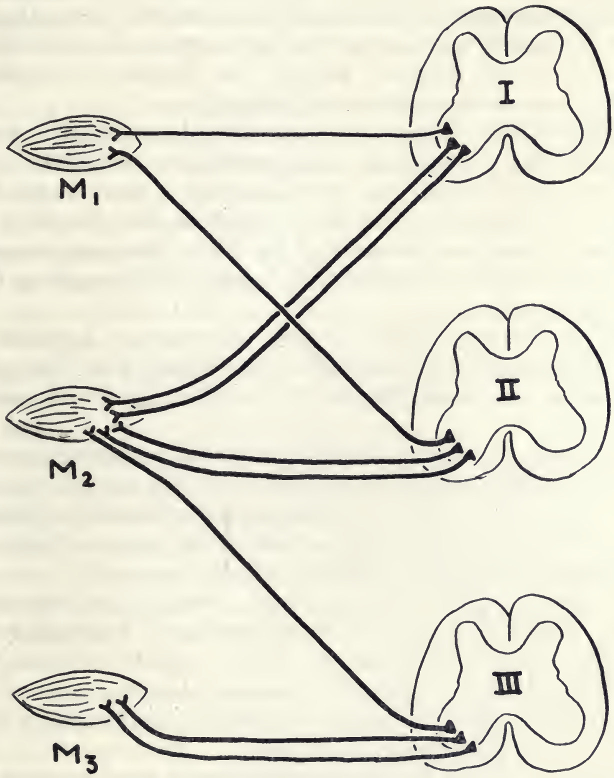

FIG. 299.—Schematic diagram of anatomical location of anterior horn-muscle lesion in infantile paralysis.

Careful muscle training, combined with gentle massage is the most natural form of re-education of weak muscles. The joints should be moved passively through a small range of motion if there is much muscle weakness in order to prevent joint stiffness. All treatments must be given in definite dosage measured in terms of muscle response carefully and frequently charted. Exercises which do not involve weight-bearing will improve the strength of weakened muscles. If too much strain is put upon these muscles as in weight-bearing, recovery will be retarded.

When underwater exercises are not readily available one may employ the simple procedure of moving a limb on a smooth, well-powdered board in such a way as to eliminate the pull of gravity during exercise of an involved muscle; the other is carrying the extremity in a sling attached to an overhead frame, allowing the extremity to swing freely through the arc in which the involved muscle contracts.

The rôle of electrical stimulation in infantile paralysis is a controversial matter in the opinion of some orthopedic men. Ober[27] blandly stated: "Electricity has no place in treatment of infantile paralysis." On the other hand Lewin[19] holds that electricity may improve the local condition in poliomyelitis and induce contractions in muscles otherwise inaccessible; in trained hands, used as a simple muscle tonic, electricity should be helpful. There is an increasing amount of clinical and experimental evidence that electrical stimulation is of definite aid in recovery of paralysis. Hansson[14] states: "I should not be surprised to see return of electrical stimulation to the weakened muscles, making the treatment of poliomyelitis similar to the care of traumatic nerve lesions."

Electric stimulation, to be effective, must be carefully planned and skilfully applied for a sufficiently long period. According to the electrodiagnostic findings, the slow sinusoidal current is used in cases showing the reaction of degeneration and the surging faradic or modulated alternating current in cases with absence of full RD. The most amenable cases for electrical stimulation are those with paralysis of one group of muscles or a few single muscles.

The most effective method of electric treatment is *unipolar* muscular stimulation, with the technique outlined in Chapter IX. The group technique is advisable only if the muscles of the extremity are all nearly evenly affected.

Smart[33] advocates the early use of graduated muscular contraction in order to keep the neighboring unparalyzed muscles in activity during the acute stages of paralysis with the consequent benefits derived from muscle movements. When muscles that have been paralyzed show signs of recovery, the graduated contraction greatly hastens recovery.

Modern research (Gila,[11] Liebesny[21]) has corroborated the earlier work of Lapicque, advocating the use of "progressive" currents in paralysis (Chapter IX). Such stimulation furnishes a slowly increasing stimulus which is able to excite the paralyzed muscles electively without affecting the normal ones. So far no suitable apparatus is available in the United States for this form of electrical stimulation.

A long time is required for the regeneration of muscles after an attack of poliomyelitis. Therefore long, persistent treatment, involving the skilful use of all available measures, is the keynote of success.

Electrical stimulation must go hand in hand with muscle re-education and be abandoned in favor of the latter as soon as there is return of active muscle power. Thermal measures—luminous heat, the whirlpool bath or diathermy—should be employed preliminary to electrotherapy. Supportive orthopedic measures must never be neglected.

When spontaneous improvement can no longer be observed electrodiagnosis may help to differentiate muscles which, though apparently inactive due to continued spasm and shortening, electrically show fairly good response. The author[18] has reported a case of eighteen years' duration in which the active power of an atrophied leg returned to the flexors of the knee after four weeks of electrical stimulation. Electrodiagnosis shows the total lack of response in some of the muscles; in case of doubt careful observation and treatment of these may be carried on for a while; if the lack of response persists then replacement of these muscles becomes a problem for the orthopedic surgeon.

THE NEUROSES

Among the so-called functional affections of the nervous system belong neurasthenia, hysteria, traumatic and occupational neuroses, various spasms, tremors, vasomotor and secretory disorders and, finally, such ill-defined symptoms as headaches, sleeplessness and nervous exhaustion. In the management of these complex conditions physical measures serve for the alleviation of symptoms, for general tonic effect and as adjuncts to psychotherapy.

Neurosis is a term frequently applied solely as a diagnosis of exclusion. It has been pointed out by Comroe[7] and others that the diagnosis of neurosis by exclusion is fraught with considerable dangers. In a follow-up study of 250 cases, organic pathological changes were found subsequently in a large percentage of cases and the following diagnoses were confirmed by autopsy, operative results or laboratory or roentgen-ray findings: abdominal carcinomatosis, carcinoma of the liver, gastric carcinoma, disease of the coronary arteries, Addison's disease, pellagra and myocardial degeneration. Of the remaining 17 cases in which evidence of organic disease had developed, the diagnoses were—diabetes mellitus, gall-bladder disease (3 cases, all proved by operation), duodenal ulcer, pulmonary tuberculosis (2 cases), ureteral stone, chronic appendicitis, Buerger's disease, suppurative mesenteric adenitis, cardiovascular renal disease with hypertension, renal calculus, uterine myoma, pregnancy, mitral stenosis and toxic goiter. It is pointed out that neurosis and organic pathological changes often coexist and either may be the forerunner of the other or they may be entirely separate from each other. Neurosis is in reality an emotional instability out of proportion to active organic impairment.

In *neurasthenics* a combination of electrotherapeutic and hydriatic measures is most valuable. For tonic effects electric cabinet baths, hot and cold douches, galvanic baths and, in milder cases, ultraviolet irradiation or the static charge or head breeze may be employed. The interrupted sinusoidal or other low-tension and low-frequency currents applied to the abdomen help to overcome the motor and secretory weakness of the digestive tract. They may also be used for general body stimulation. Sexual weakness of neurasthenics often responds very well to the low-frequency stimulation of the prostate. Cerebral galvanism or diathermy may be applied in patients with stubborn head symptoms.

In contrast to neurasthenics, *hysterical patients* do not seem to take kindly to electrotherapy. Electrical measures should be only used as a last resort and preferably for definite pathological changes. Faradism is recommended for hysterical aphonia; the shock of painful stimulation may bring back phonation. For paralysis, spasms and the variety of other disorders, static sparks, the interrupted sinusoidal or the Oudin current may be applied.

In *sleeplessness* due to nervous exhaustion a full or three-quarters cold wet pack is a classical treatment measure. In cases of low blood-pressure the static modalities may be helpful. General light baths may be also effective. Turrell recommends gentle stroking of the forehead while the patient sits on the autocondensation chair, thus drawing off a mild amount of current. Intense applications of light along the spine have also been recommended. General massage exerts remarkable hypnotic effect in some patients.

Vegetative Neurosis.—Attention has been called by Neergard[24] to the fact that so-called vegetative neurotic symptoms occurring in many middle-aged people in spring and fall, and consisting in fatigue, vertigo, headache, neuralgic pain, as well as such mental signs as moodiness, irritability, etc. are in fact due to infection with a filtrable vaso- and neurotropic virus; repeated encounters with small amounts of this antigen lead to sensitization and allergic reactions and these form the basis of the vegetative-neurotic syndrome. The aim of physical therapy in these cases is to increase the immunobiological process through "desensitization" by a course of either cold or hot hydrotherapeutic application according to the patient's sensitivity. The good results with such a régime erroneously called "suggestive" are in fact due to the stimulation of the regulatory powers of the organism and the overcoming of the somatic syndrome.

Traumatic Neurosis.—In the treatment of traumatic neuroses a puzzling picture confronts medical men. The emotional state of the patient is a combination of fear of disability (anxiety), resentment toward the agent responsible for the injury and toward any one, such as the doctor, suggesting that the injury is physically negligible. There is almost always a characteristic reaction of the patient to therapeutic effort. There is a tendency to blame any medicine or other therapeutic agent for the continuation or exacerbation of these symptoms.

However, the term post-traumatic neurosis should not be used as a waste-basket into which diagnostic failures are thrown. Traumatic neuroses are recognizable by a definite symptomatology and the salient points of their classification are as follows (Hall and Mackay[13]):

Post-traumatic neurasthenia exhibits abnormal fatigue and irritability, associated with extreme emotionalism and a disproportion between the actual strength of the patient and his supposed weakness.

Post-traumatic anxiety neurosis is characterized by a marked hypochondria which concerns itself chiefly with one organ or symptom until it becomes almost an obsession. A typical anxiety headache is often present which is usually not a true pain but rather a sense of weight or pressure and is very often constantly present for days in contrast to the intermittent headaches of organic origin. Finally there are symptoms of overstimulation of the sympathicus; excessive sweating, cold clammy hands, tremulousness and dilated pupils.

Post-traumatic hysteria: patients exhibit pseudo-organic signs and symptoms: blindness, deafness, paralysis, anesthesias and disturbances of motion or gait. It is characteristic that these signs do not correspond to actual anatomical relationship but rather to the patient's idea of anatomical relationship, such as "stocking and glove" anesthesias, complete paraplegia without sphincter disturbance and the like. These patients also manifest an abnormal degree of suggestibility. Post-traumatic hysteria is the most frequent among the functional nervous conditions.

Traumatic neuroses are among the most baffling problems of physicians dealing with traumatic conditions, and physical therapy departments are constantly confronted with these trying cases. Hall and Mackay[13] advise that instead of arguing with the patient, one should make oneself his friend, secure his confidence by listening patiently to his story. It is absolutely necessary that all financial controversy be settled once and for all—in the form of a lump sum. The next step is the re-establishment of the patient in some form in which he can transfer his attention from himself to outside interests; this may be possible only after intensive suggestion. "To expect the patient to become free from all symptoms without treatment is almost equivalent to expecting him to admit that his symptoms were 'unreal.' Therefore, medication, various forms of physical therapy or electrotherapy are very useful in giving him reason to expect improvement and a basis for relinquishing his symptoms. Such methods, however, must not be unduly prolonged, as they only fix the patient's attention too firmly on his ailments."

MENTAL CONDITIONS

In the large field of mental disorders, physical measures especially in the form of hydrotherapeutic procedures find wide application for either stimulation or sedation. Overholser[29] recognizes two classifications of physical therapy in psychiatric patients. One includes the types prescribed primarily on account of the total behavior of the patient, *i. e.*, on account of his mental condition, such as the continuous bath and the wet sheet pack for states involving tension, overactivity and restlessness, and the various forms of stimulative therapy, such as the contrast douche, the salt glow, the friction rub and ultraviolet irradiation, which may be used in states of depression and decreased motor activity. In the other group are included numerous other forms which are useful even though they are directed toward systemic conditions or conditions of particular organs.

Among the conditions frequently encountered are traumatism, arthritis and rheumatic conditions, etc. There is no question but that the attention given to incidental conditions in these patients is well repaid. The systematic application of physical measures as treatment adjuncts increases the patients' well being and reacts favorably to their mental state constituting a direct approach to their psychical self.

Sedative physical therapy is indicated in excited patients, those with manias, epilepsy, toxic and organic conditions and some with schizophrenia; continuous baths, warm needle sprays, Scotch douches, and hot fomentations are useful for this purpose. Cold or warm wet packs are usually contraindicated because the element of restraint produces fear. Most patients like the continuous bath best; a temperature between 94° to 96° F. is the most desirable in excited patients. One must be alert to the potential dangers of continuous baths in excited, debilitated patients such as stroke, cardiac collapse; there exists also the ever present possibility of suicide and drowning. Cold sitz baths reduce sexual tension.

Stimulative therapy is indicated in apathetic, stuporous and catatonic patients with schizophrenia and also certain hysterical individuals. According to Barnacle,[1] the psychiatrist is attempting to interest the patient in reality through stimulation. Alternating hot and cold sprays, Scotch douches, salt rubs and general massage are indicated. In the author's[17] clinic at Manhattan State Hospital dementia precox cases, if not too far deteriorated showed some improvement in their mental state and became more easily manageable following general stimulation by ultraviolet radiation or the static bath. Postencephalitis cases became more alert and showed increased emotional stability following the same measures, also in some instances following cerebral galvanism. Most of these patients showed improvement in their general physical condition, weight and nutrition. Barnacle states that electric light cabinet treatments should be used cautiously for so-called elimination in chronic alcoholic and other toxic conditions, because in alcoholics, delirious and convulsive reactions may follow intense heating. In paranoid reactions physical treatment is likewise contraindicated, because the mechanical procedures and apparatus are likely to be misinterpreted as persecution.

Overholser emphasizes that it is not a criticism of physical therapy or of any other branch of medicine that it produces psychologic effects. The tangible effects of the various procedures are demonstrable and well known. That there are positively suggestive effects at the same time simply re-enforces the local effect and serves as an adjuvant if one recognizes those effects; by ethical and wise utilization of them, the welfare of the patient is promoted and the desired therapeutic result is hastened. Hence any well equipped psychiatric hospital needs to have an active physical therapy department. Patients in mental hospitals exhibit little difference from patients outside. They are perhaps more susceptible to the intangibles, atmosphere, personality, attention to their needs and interest shown in them. The physical therapy department should be made as attractive as possible. Such details of atmosphere do much to promote relaxation, stimulate coöperation of the patient and put him in a psychologic condition to receive maximum benefit from treatment.

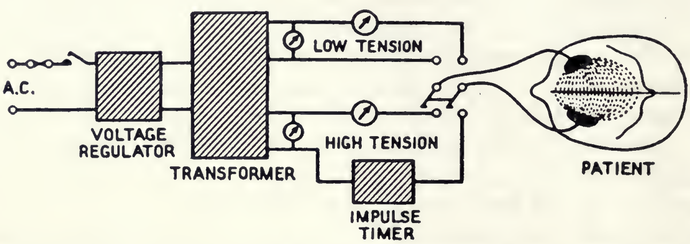

Fig. 300.—Diagram of electric shock treatment. (Fleming *et al.*; courtesy of Lancet.)

Electric Shock Therapy.—Cerletti and Bini, in a quest for a safer measure to produce convulsions in schizophrenia than by chemical shock (insulin), discovered that an alternating current of 125 volts can be applied to the human head once or repeatedly without causing damage and that the therapeutic effects of such an electric shock in a number of mental conditions are highly satisfactory. These observations were quickly corroborated by other psychiatrists; suitable apparatus was developed and the scope of application of the new method and its most effective technique received much study in recent years.

Apparatus and Technique.—Most of the apparatus used employ the commercial alternating current, its voltage modified by a step-down transformer and the length of its flow controlled by a time switch. Berkwitz[4] has constructed a portable apparatus, in which a 6 volt dry cell energizes an induction coil of the model T Ford spark coil type. Figure 300 shows the diagram of one type of apparatus in which there are two circuits, a low tension circuit through which the efficacy of the electrode contact is tested and the resistance in ohms is computed; and then switching over to the high tension circuit is done. It takes from 80 to 120 volts, flowing for 0.2 second to produce a shock, with the electrodes applied to two sides of the forehead.

Rahm and Scarff[31] constructed with the aid of a thyratron tube and suitable condensers a simple yet very efficient stimulator calibrated in volts, which enables excitation of the cortex with stimuli of two to four volts, and the use of a choice of frequency ranging from 7.5 to 960 per second; all this is done without any extra computation.

Electrodes are applied either biparietally (Fig. 300) or to the forehead and the nape of the neck. Various clinicians apply stimulation slightly varying in duration and strength but they all agree that the production of a fairly strong convulsive response is essential; if the dose is too small only a few muscular twitchings will occur. Treatments may be administered two or three times weekly in the morning on a fasting stomach. Patients should be placed on a padded wooden table with a hard pillow under the dorsal spine to prevent vertebral fractures. Metal articles such as bridges and hairpins are removed.

Physiological Effects.—Electrocerebral shock causes mass cerebral and autonomic nervous system irritation, the manifestations of which are profound effects on heart-rate, blood-pressure, pupils, state of muscular tonus, mental equilibrium, etc. With electric shock administered at suitable strength and duration patients lose consciousness immediately and undergo a typical epileptic fit: there occurs first a generalized tonic contraction, lasting about ten seconds in which the face is flushed; this is followed by a clonic stage, in which the face may become cyanosed with frothing at the mouth, wide dilation of the pupils and at times evidence of urine and feces. The average duration of the fit is fifty seconds. The recovery varies in each patient: some walk away from the treatment couch —others sleep for several hours; some are confused or delirious—others apologetic.

The advantages claimed for electric shock therapy over the other convulsive methods are: (1) the patient does not experience pain and does not, therefore, resent treatment; (2) since no toxins are introduced into the system, pulmonary and myocardial complications are avoided; (3) psychomotor excitement similar to that following cardiazol convulsions is not present; (4) difficulties involved in intravenous medication do not arise; (5) if no convulsions ensue, the treatment can be immediately repeated; (6) the method requires little time and expense. By this time the electrical method of shock treatment by its marked advantages of accuracy and control has almost completely replaced shock treatment by chemical means, just as fever treatment by physical means has completely superseded malarial treatment in central nervous system affections.

Several explanations have been offered for the working mechanism and the results obtained by electric shock therapy. Gronner[12] states that much more happens to the patient under treatment than passage of a weak current through his head for 0.3 second twice a week. He receives repeatedly the benefit of short amnesias which tend to converge and may constitute a powerful aid in removing conflictual material and in decreasing the compulsive quality of psychotic thinking or action. Experiments on animals have shown that damage to the ganglion cell is present, though temporary and reversible. Apnea lasting up to one minute undoubtedly causes anoxia and some alteration of brain metabolism. Basically, it probably represents a change of milieu, in biologic terms. In attempts to correlate somatic and psychologic variations, electro-encephalographic readings have shown abnormalities with psychotic manifestations but have failed to demonstrate that an anatomic substratum exists for improvement or failure.

Therapeutic Indications.—Cerletti originally proposed that electric shock treatment be given preference in depressive states, especially in those with psychomotor inhibition or retardation, and in most schizophrenics. Clinical experience during recent years has proved that this treatment is most effective in involutional melancholia and manic-depressive psychosis. Manic patients do not hold their recovery as well as those who have an agitated depression. There is no evidence to indicate that electric shock may prevent future psychotic attacks, or that it might interfere with spontaneous clinical recovery. According to Smith, *et al.*[34] on the other hand, it is not effective in treatment of schizophrenia and is of doubtful value in treatment of psychoneuroses.

Kalinowsky[16] stresses the efficacy of electric convulsion treatment in acute schizophrenia if the number of convulsions is sufficient; discontinuation of treatment after the usual early clinical improvement almost invariably leads to relapse and is the most important reason for its failure.

Neymann[26] believes that neurotic patients, except extremely recalcitrant ones, should never be treated by shock therapy. They are accessible to psychotherapy without temporary dulling of their mentality. Shock therapy only serves to disturb a psychoneurotic patient and often produces permanent fear of dementia because he becomes acutely aware of his retrograde amnesia or lapse of memory.

Complications and Dangers.—Complications of electric shock therapy are similar to those of other types of convulsive shock treatment but are less frequent. They include dislocations of the mandible, ligamental tears, and dislocations and occasionally fractures of the arm or clavicle. As in cardiazol therapy, the danger of a flare-up of latent tuberculous infection is stressed by some authors. Contraindications include severe cardiovascular renal disease, especially endocarditis, thrombophlebitis and decompensated heart diseases; pulmonary diseases, especially tuberculosis; acute infectious or febrile diseases and extreme debilitated states in which susceptibility to fracture might exist because of deficiency and disturbances of calcium metabolism. The review of the litrature indicates that the cause of death after electric convulsion treatment is still obscure.

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CHAPTER XXVIII

AFFECTIONS OF PERIPHERAL NERVES

General Considerations. Peripheral Nerve Injuries. Neuritis. Facial Paralysis (Bell's Palsy). Brachial Neuritis. Sciatic Neuritis. Meralgia Paresthetica. Trifacial Neuralgia. Intercostal Neuralgia.

General Considerations.—In treatment of affections of peripheral nerves physical therapy plays an important rôle because due to the comparative accessibility of the affected parts, intelligently applied physical measures often give prompt relief, shorten the period of disability to a great extent and, in painful inflammatory conditions, lessen the need of sedative medication considerably.

There are two principal groups of peripheral nerve affections: traumatic and inflammatory. Following a lesion of a peripheral nerve, loss of motor function, sensory disturbances and trophic changes produce a varied clinical picture and the effective employment of physical measures for the relief of these symptoms as well as for the treatment of the underlying condition demands a knowledge of the cause, location, extent and stage of the lesion. This is at times simple and at other times quite difficult. Electrodiagnosis in some instances, such as in facial paralysis, in hysteria and in malingering will be invaluable for diagnosis and prognosis.

Table 55.—Symptomatic Differences Between Central and Peripheral Lesions

Lesions of central neuron	Lesions of peripheral neuron
Type: Hemiplegia	Type: Anterior poliomyelitis Peripheral nerve injuries
Spastic paralysis	Flaccid paralysis
Slight atrophy	Marked atrophy
Reflexes increased	Reflexes lost
No RD	RD present

PERIPHERAL NERVE INJURIES

Pathology and Diagnosis.—Injuries of peripheral nerves can be brought about by falls, blows, dislocations, fractures, penetrating wounds, or by continued pressure. The anatomical changes in the nerve may be a contusion, laceration or division, with a loss of motor power—flaccid paralysis—and loss of sensation in the part supplied by the nerve involved. There will be immediate complete or incomplete paralysis in the muscles supplied by the injured nerve.

The microscopic changes and the coincident or subsequent syndromes will vary according to the extent of the trauma and its circumstances. There are immediate or gradual loss of function in the affected parts, sensory changes, and typical posture. Histologically, in the distal part of the injured nerve, total or partial degeneration of the axis cylinder and muscle sheath occurs, while the affected muscle first shows fibrillation. Later its fibers become pale, shrink in size, and, if unsupported, stretch indefinitely. Coincidentally, typical changes in the electric excitability of the nerves and muscles occur, and there are also characteristic chemical changes in the muscles.

The muscles supplied by the nerve become weakened or fully paralyzed and suffer from lack of nutrition, due to the separation from their trophic center and lack of exercise. They also suffer from overstretching by their strong antagonists if allowed to remain in a faulty position. The other soft parts, joints, bones and tendons suffer from lack of nutrition and may develop adhesions, faulty positions, trophic ulcers and other pathological conditions.

Unrecognized and unskilfully treated nerve injuries are important causes of permanent disability of individuals injured in industrial or other accidents. All medical men should, therefore, be familiar with their early recognition and their effective treatment. The principal signs of the most frequent forms of nerve injuries are shown in Table 56.

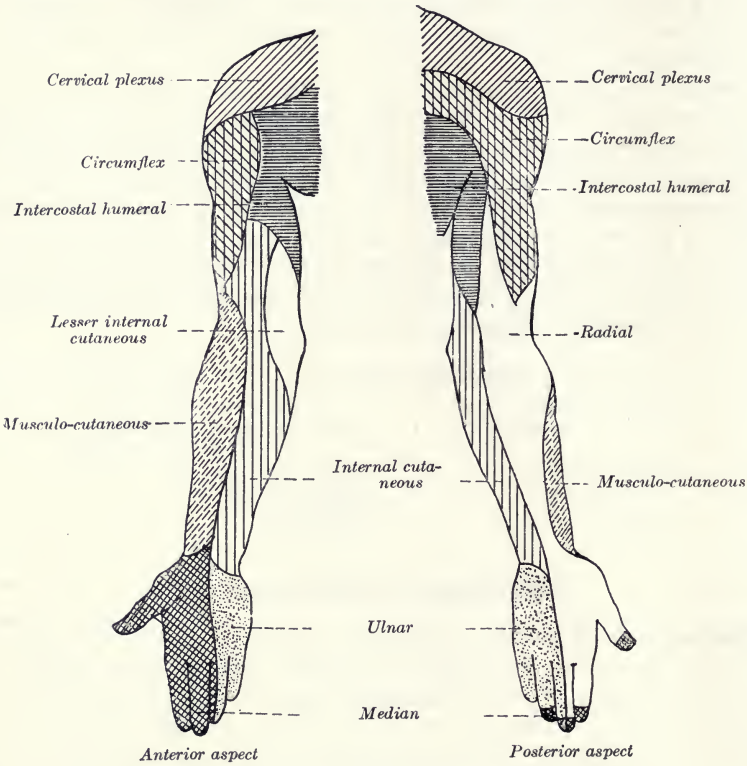

Fig. 301.—Areas of cutaneous sensibility, upper extremity.

In many cases it is clinically impossible to ascertain at first whether the vitality of the nerve axons has been sufficiently damaged or broken to cause progressive nerve degeneration below the site of injury. Electrodiagnosis, as described in Chapter VII, will enable a differentiation to be made after ten days or so between injuries leading to RD and those which do not.

Sensory changes manifest themselves in areas of anesthesia corresponding with the sensory area of the affected nerve or nerves (Figs. 301 and 302), in loss of deep sensation, at times hyperesthesia or paresthesia with abnormal sensations of burning and tingling. At times the patient may complain that the part feels lifeless.

Contrary to an erroneous conception persisting in some minds, there is no electrical test available which will ascertain whether or not there is a separation of nerve fibers to such an extent that spontaneous regrowth is impossible. In case of penetrating injuries the surgeon must decide on purely anatomical considerations whether to make an immediate nerve suture or not. Contrary to another belief curiously persisting in some minds, even immediate nerve suture does not prevent subsequent nerve degeneration. In the majority of suspected incomplete nerve lacerations the tendency now is to wait and to make an exploratory operation only if (1) there is total loss of function for two months or more in an area

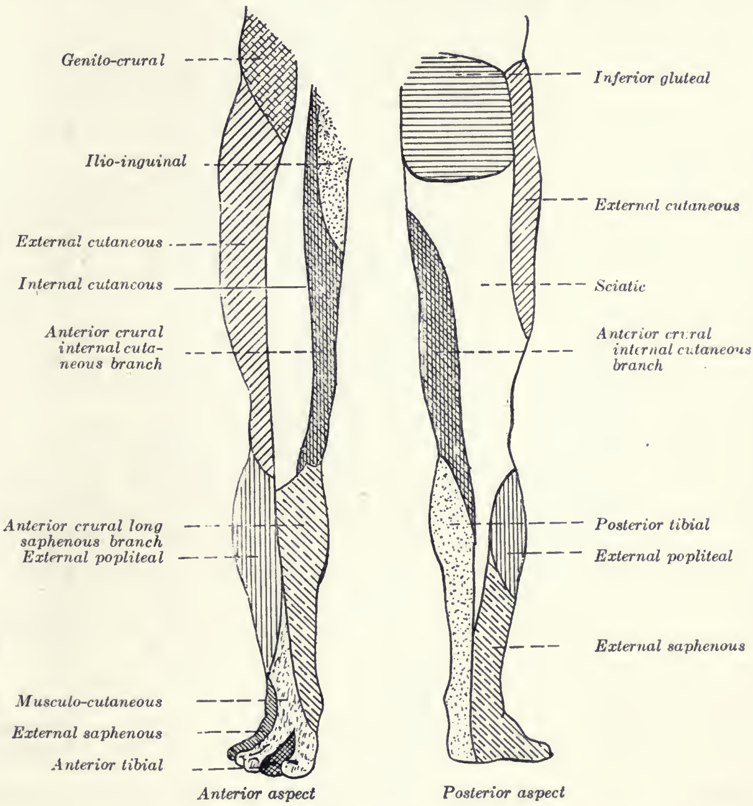

Fig. 302.—Areas of cutaneous sensibility, lower extremity.

exclusively supplied by a nerve or (2) if recovery is extremely slow or there is a relapse or (3) if there is a palpable neuroma at the site of the injury of a nerve, the function of which is seriously disturbed or (4) there is severe, persistent and intractable pain.

Treatment.—"Physical therapy holds the first place in the treatment of peripheral nerve lesions; operative procedures of suture and neurolysis will not serve to restore function. They only make it possible for the nerves to regenerate" (Pollock[8]). As long as in an injured nerve its ends remain in close anatomical approximation, regeneration of the nerves takes place automatically by the descent of new axis cylinders from the intact central end at a rate of from 1 to 2 mm. a day, about 1 to 2 inches per month, but restoration of nerve function occurs much later. The anatomical regeneration of the nerve can only be assisted indirectly by improvement of the circulation and nutrition.

TABLE 56.—SUMMARY OF MOST FREQUENT FORMS OF PERIPHERAL PARALYSIS

	Frequent causes	Missing function	Typical appearance	Sensory loss	Type of splint
Facial	Fractured skull, facial wounds, operation	Wrinkling of forehead, closing of eye and corner of mouth	Lack of expression, drooping of lower eyelid; face pulled to sound side	None	Prevent sagging of the face by elastic or adhesive straps.
Circumflex	Dislocation of shoulder	Abduction of arm; external rotation weak	Shoulder flattened	Over middle of deltoid	Abduction splint for upper arm.
Musculospiral (radial)	Fracture of humerus, wounds on upper arm	Extension of wrist and metacarpophalangeal joints; grip weak	Drop-wrist infolding of thumb; little trophic change	Small area at base of the thumb and index finger on dorsum of hand	Forearm in cock-up splint up to proximal interphalangeal joint
Ulnar	Injuries at the elbow or wrist	Finer movement of the fingers (spreading)	Claw-hand; first finger joints in hyperextension, other 2 in flexion	Little finger, half of ring finger, ulnar side of hand to wrist	Abduction splint for upper arm.
Median	Injuries at the elbow or wrist	Coarser movements of hand and opposition of thumb	Flat or ape-hand, marked trophic changes	Larger thumb, index, middle and half of ring finger on palm; corresponding area on dorsum except thumb	Abduction splint for upper arm.
Brachial plexus (also Erb's paralysis)	Dislocation of shoulder; forcible traction of the arm (indirect violence) obstetrical paralysis	Varies with involvement of different roots	Varies with involvement of different roots	Usually small except when whole plexus involved	Varies with extent of involvement.
External popliteal	Wounds about head of fibula; pressure of cast	Dorsi-flexion of leg and extension of toes	Drop-foot	Dorsum of foot, outer side of leg	Straight angle splint.

NOTE.—For extent of missing motor and sensory function of other types of peripheral paralysis see charts in Appendix.

It is conceivable that perfect regeneration might occur in the nerve and an extremity be functionless, because of interphalangeal fibrosis, retraction of capsular ligaments, marked atrophy and fibrosis of muscles, shortening of muscles, spasms of muscles and ankylosed joints. Hence, according to Pollock[8] when a primary or secondary suture is indicated immediately, physiotherapeutic treatment must assist the operative procedure. When it is felt advisable to defer the operative procedure, physical therapy must be initiated promptly to the end that when the nerve regenerates it will activate a mechanism capable of adequate movement.

The official U. S. Army Report on Physical Reconstruction,[6] issued at the end of World War I, outlines the duties of the physical therapy department in cases of nerve injuries as follows: "In the physiotherapy treatment of nerve injury cases it is essential that the director of physiotherapy make a clinical examination, together with a brief history. The following notations should be included on a suitable clinical record form: cause and date of injury; date of healing of wound; time of appearance of paralysis in relation to injury; treatment up to present time, including surgical measures; muscle groups paralyzed; area of sensory impairment; degree of atrophy; extent of fibrosis; presence of trophic ulcers; vasomotor changes and neuromata; information on the 'D.T.P.' (distal tingling on percussion); measurement of girth of affected limb as compared with the opposite or normal limb, and measurements with suitable protractors of any limitation of joint mobility, if such is present. The electrical reactions should be taken, following which the specific treatment should be outlined, with proper instructions to the aide to whom the case is referred. A report is then sent to the surgeon of the findings of the electrical reactions, stating in terms of pathology the condition of the nerve as interpreted from the reactions, and the outline of treatment which the patient will receive. A monthly progress note and report to the surgeon is in order, with special reference to any material changes in electrical reactions, return of sensory or motor functions, progressive advancement of the D.T.P., and the like. The practice of personal consultations with the surgeon who has charge of the patient can well be emphasized."

TABLE 57.—PHYSICAL TREATMENT MEASURES IN NERVE INJURIES

Form	Object	Period of use
Splinting	Prevention of deformity	From beginning
Heating	Improvement of circulation and nutrition	From beginning
Electric muscle stimulation	Preserve functional capacity of muscles	From beginning
Passive movement	Prevent fibrosis and contractures	From beginning
Massage	Aid circulation, improve nutrition	From beginning
Active exercise	Re-education of muscle function	In later period
Occupational therapy	Hasten muscular recovery	In later period

The judgment of an experienced physician usually combined with the skill of an expert technician is required to carry on the physical treatment of a severe nerve injury through its various stages.

Splinting is a physical measure of primary importance in maintaining the condition of paralyzed muscles and assuring a position of anatomical rest and complete relaxation of all paralyzed muscles. It will also prevent shortening of their antagonists. Splinting is absolutely essential in every case of nerve injury, because even the most painstaking form of electrical exercise applied for a short period daily cannot possibly overcome the potential harm caused by the continuous drag of the antagonists when proper splinting is neglected. On the other hand, splinting should not be kept up indefinitely as prolonged immobilization in itself will cause periarticular joint changes and muscle atrophy. Many patients have been incapacitated by the fibrosis which has resulted from the prolonged and uninterrupted use of splints. Splints must be simple, light, easily applied and removed. Table 56 also indicates the type of splints indicated in the principal forms of nerve injuries.

Thermal Measures.—The object of thermal measures is to improve nutrition and relax muscles and prepare the limb for further treatment. The most convenient and safest measure for this purpose is the hot whirlpool bath, at a temperature of 100° to 105° F., in which the affected extremity should be submerged for at least half an hour. When it is not available, a heat lamp or infrared generator may be applied. Because of the frequent prevalence of disturbed sensation, impaired circulation, and other trophic changes, all heat measures must be applied very cautiously in order to avoid the production of slowly healing burns. For the same reason the use of diathermy in these cases should be reserved for expert hands. It has been argued that diathermy exerts a more efficient heating effect in extensive muscle atrophy and that in early cases it may retard or arrest muscle fibrillation which, according to Langley, always follows severance of the nerve and is the cause of muscle atrophy. Short-wave diathermy is best applied with the inductance cable wound around the extremity and kept up for thirty minutes at a rate of moderate heating. Any method of heat treatment should be applied systematically, preferably daily, to accomplish the best results.

Electrotherapy.—English and French authors, notably Tinel[9] state that the simple passage of a galvanic current seems to be able to stimulate regeneration of a nerve.

Electrical stimulation is the main therapeutic standby in improving the condition of the paralyzed muscles. The principles and technique of electrical stimulation in paralysis have been presented in Chapter IX. The slow sinusoidal current, beginning with two or three contractions of each muscle, is used at the beginning and gradually increased. In cases with partial RD or only slight quantitative electrical changes, more vigorous stimulation may be employed. Pollock believes that stimulation by the interrupted galvanic current although often painful is as useful as that produced by any other type of galvanic current; the suddenness of contraction can produce no harm after the second week following injury or surgical procedures, if the muscles are kept practically at rest during the first two weeks in which they are fragile and are easily bruised. Overtiring, however, must always be avoided. Active exercise is instituted as soon as there is any indication of return of active power.

Electrical stimulation, along with other adjuvant treatment, must be continued systematically. Corresponding with the progress of anatomical regeneration of the nerve, the atrophy of the muscles gradually disappears and their response improves. Testing by the condenser set or for chronaxie (Chapter VI) every four to six weeks enables charting of this progress in figures. After many weeks or months a time comes when there is the first indication of return of voluntary motion in one or more of the paralyzed muscles. This is proof that the nerve trunk and the motor end-plate have regenerated. Response to the faradic current returns about this time or, as a rule, somewhat later. One must be careful not to replace the slow sinusoidal too quickly by the surging faradic or interrupted sinusoidal current, for recovering muscles are sensitive toward more exhausting exercise and may be easily tired out.

Massage.—Massage as an aid to circulation and for the improvement of nutrition is a useful part of the routine physical treatment. So far as the prevention of muscle atrophy is concerned, massage is only of slight benefit. As a matter of fact, according to Mennell, heavy massage is transmitted to the blood-vessels and may cause paralytic dilatation. Massage should be always preceded by a thermal measure and administered to the well-supported and completely relaxed extremity. It should begin with rhythmic superficial stroking and continue with gentle kneading of the skin and of any contracted muscles, with friction over ankylosed joints. The average massage treatment should take from ten to twenty minutes.

Passive Movement.—Suitable manipulation of joints and stretching of muscles in peripheral nerve injuries is of even greater importance than routine massage; however, it is best carried on in conjunction with massage. Contractures and adhesion of joints, muscles, and tendons are due to shrinkage of newly formed connective tissue. Introductory heating and massage tend to soften this tissue and to promote its absorption, while gentle manipulation serves to stretch it and slowly free it. Such manipulation will also enable normal joints to keep active and increase the range of motion in those which already have become impaired. In manipulating a joint it is better to increase the movements which are not so much limited, and in the course of their restoration to normal, gradually to limber up the most obviously limited movements. The latter are resisted by the strongest adhesions. There is no reason for stretching under anesthesia in these cases because this is likely to cause considerable damage to the capsule and the periarticular tissues. Early and skilful employment of suitable passive movements and manipulation is the best preventative of the formidable ankylosis and contractures. In order to make possible this early treatment, splints must be removable, and in case of nerve suture passive movement should be instituted as soon as the condition of the scar permits—usually after two weeks.

Active Exercise.—Active exercise and re-education of muscle function comprise the most important part of the treatment after active power to the affected muscles has begun to return. This occurs, as a rule, not earlier than the fourth month after injury. However, a nerve injury causes loss of function of an extremity far beyond the structures that are actually involved, because the normal use of the extremity has been lost. Furthermore, the usual routine of splinting and immobilization tends to cause patients to restrict the use of the limb to a minimum. The early use of suitable exercises will reduce much of the unnecessary waste of muscles and stiffening of joints. Hence, even in the early treatment of nerve injuries, exercises are indicated for maintaining the function of muscles not directly affected and also for maintaining the full range of joint motion. When signs of active power appear in the affected muscles, the simplest possible active exercises with these muscles are begun, at first with as much assistance by the technician as required. Movements on a powdered board or under water will greatly aid in overcoming gravity and in allowing gradual redevelopment of function in the very weak muscles. Exercises must be carried on in all instances with the parts properly supported and previously warmed. It is very rarely necessary to use artificial exercise apparatus for this purpose, but use can be made of the various types of simple active exercise devices that are available. Overexercising must be avoided at all times.

Occupational Therapy.—The last stage of muscle re-education consists in active stimulation of the patient's efforts by occupational therapy. A well-equipped and supervised work shop, where various simple tools provide practical and attractive work, is most desirable for this purpose. The same set-up can be used in cases where there is lack of recovery, to teach the injured to make the best use of what remains to him. Gymnastic exercises are also valuable in this stage for general muscle redevelopment and increase of coördination.

NEURITIS

Pathology.—Neuritis is a painful, degenerative and often inflammatory process in any part of the peripheral neuron, causing functional disability. This functional loss according to the anatomy involved may be sensory, motor or mixed. The element of pain may be extremely mild and evanescent, as in lead poisoning and infantile paralysis. The symptomatology often indicates the location of the primary pathological changes in one part of the nerve fiber, such as in the dorsal root ganglion (causing herpes zoster and localized pain in the course of the nerve or in the terminal filaments of the skin). The pathological changes vary greatly in the different forms of neuritis, with a multitudinous etiology.

Classification.—The division of neuritis into a generalized and localized form is important from the standpoint of rational physical therapy. In *polyneuritis* of the rheumatic type general heat measures and at times fever therapy, are indicated and as a rule helpful; increased elimination by such measures is also to be considered in some of the toxic types, due to chemical poisoning. In deficiency types, ultraviolet irradiation may be of definite value in disturbed calcium metabolism. Artificial fever therapy is justified in severe or resistant types and has been favorably reported on, recently, by clinicians (Bennett and Cash[1]). Only mild fevers of 103° to 105° F. for two to four hours each for two to six treatments are indicated. Due care is essential to prevent burns because of anesthetic parts of limbs.

Localized neuritis caused by trauma or pressure is one of the most prevalent forms and offers a most extended field of applicability for proper physical therapy, both for causal treatment and for symptomatic relief. The ultimate outcome in all forms of localized neuritis will depend on the removal of the exciting cause, and at times is a straight surgical problem. A definite diagnosis as to the cause, extent and stage of neuritis is essential; at times this is quite difficult. It is evident that physical therapy will always best work in conjunction with other indicated procedures.

Neuralgia denotes a pain in the distribution of a sensory nerve, due to an irritative lesion anywhere in the sensory tract but without pathological changes in the nerve itself. However, the dividing line between neuralgia and neuritis is by no means definite. Treatment in these cases depends, just as in neuritis, in the location and removal of the source of irritation. Physical measures play the same rôle in the management and therefore there is no reason to separate discussion of the so-called neuralgias from the large group of neuritides, to which they properly belong.

Relief of Pain in Acute Neuritis.—Generally speaking, one is called upon most frequently to treat one of the two principal symptoms in the acute stage of neuritis, paralysis or paresis—when a motor nerve is involved, or pain and the various paresthesias when sensory nerves are affected. The methods of treating paralysis have been dealt with in Chapter IX and in the preceding chapter; therefore, only the clinical aspects for the relief of pain will be presented here.

The pain in neuritis is usually sharp or aching, and may be localized, or it continues along the course of a nerve. It is usually accompanied by tingling, numbness or loss of sensation; the nerve is tender to pressure and there may be tenderness all over the affected area. The knowledge of the location of the painful areas described by Valleix is important, because local measures directed for the relief of pain will be most efficient when applied to these.

Patients suffering from neuritic pain, which at times may be of torturing intensity, instinctively seek rest and relaxation for the affected area, and the first effort of the physician should be to secure as much of this as possible. Light splinting, avoiding pressure of bandages or carrying an affected limb in a sling may help considerably and will protect the patient from accidental touching or pushing the affected area while going about. It is indeed quite a problem whether in acute neuritis with very severe pain the relief obtained by any form of office treatment is worth the effort and risk of traveling from a distance. The portable apparatus now available helps to solve this difficulty, because it allows the institution of physical measures in the patient's home. In other cases mild sedatives help to overcome the temporary aggravation due to the exertion and enable ambulatory treatment when it is essential for combating the underlying pathology.

Diathermy is the measure of choice in the average case not only for obtaining relief from pain but also for influencing its most frequent causes, *i. e.*, pressure and muscle spasm. Instances of immediate relief from pain upon removal of pressure by an abscess or constricting band are well known.

In administering diathermy it is advisable to precede it by five to ten minutes' application of radiant heat to the area to be treated, and this radiation may be continued during the entire treatment. With short-wave diathermy one condenser pad is placed well above the spinal center of the affected nerve, the other along its peripheral origin, so as to include the area of painful sensation. The inductance cable offers another and possibly more effective method of heating an entire extremity. The current should be pushed up slowly to comfortable toleration which will vary according to the sensitiveness of the patient. One must avoid an amount of current which causes throbbing or marked exacerbation of pain during treatment. A slight increase of pain immediately following treatment, however, is not a contraindication for repeating it within twenty-four hours or even more often, provided that there is some relief of the pain in the periods between treatments.

It is usually advisable to follow diathermy by the monoterminal (Oudin) current applied through a condenser or vacuum electrode over the painful area. This adds mild counterirritation of the skin to the analgesic and resorptive effects of deep heat. In instances where sensitiveness is so great as to interfere with the application and fixation of diathermy electrodes luminous heat or infrared radiation followed by a very mild Oudin current may give relief. Treatments should be applied daily or even twice a day at first and be continued as frequently as necessary to keep the patient comfortable. The gradual relief thus given allows one to dispense with sedatives and narcotics.

In resistant cases the galvanic current may be employed. Electrodes should be applied so as to include the entire affected area. The current is pushed up gradually to maximum toleration. It has been emphasized by Kowarschik that the current should be applied for long treatment periods, at least thirty to forty minutes at a time. Histamine and mecholyl ion transfer have been employed in recent years with some success and are offering an alternate measure worthy of trial.

Reports on the usefulness of local ultraviolet radiation administered to a degree to produce a mild dermatitis have been explained by counter-irritation. A mild non-specific protein reaction due to reabsorption from the area of the mild burn may also play a rôle in the relief produced.

In particularly resistant cases of sciatic and brachial neuritis fever therapy was employed by Bennett and Cash[1] with a measure of success, but not comparable to the almost complete relief obtained in toxic infectious polyneuritis.

Chronic Neuritis.—In long-standing cases of neuritis, fibrositis develops, causing pressure and contraction of scar tissue around the nerve. This occurs especially in chronic sciatic neuritis. In these cases thermal applications should be followed by a mechanical measure, in order to break up perineuritic adhesions, to exercise flabby muscles and to tone up the tissues. Low-frequency stimulation by modulated alternating current or surging faradism is often helpful. Skilful massage and therapeutic exercise, acting on the principle of limbering up the parts, have also proven valuable. Good results have been reported also with roentgen-ray treatments which are explained by selective absorption of scar tissue.

In particularly resistant and fairly definitely localized cases of chronic neuritis galvanic acupuncture with the technique described in Chapter VIII may be employed.

SPECIAL FORMS OF NEURITIS

Facial Paralysis (Bell's Palsy).—The seventh cranial nerve is a pure motor nerve and supplies all the muscles of the face, except the masseter. It has three branches, the upper one supplying the closing muscles of the eye, the other two the muscles around the nose and mouth. The nerve follows a tortuous course from the floor of the fourth ventricle through the inner ear and emerges through the stylo-mastoid foramen in front of the external auditory canal, passing through the substance of the parotid gland. Due to its anatomical relationships many conditions may affect the nerve; an important differential diagnostic point is that lesions due to cerebral hemorrhage, pressure of a new growth or softening of the brain usually do not affect the upper branch of the nerve, and in these cases the closure of the eye and wrinkling of the forehead remain unaffected. Traumatism, such as fractured skull, mastoid operation or wounds of the face, usually affects the main nerve trunk and results in immediate paralysis of all muscles of the affected side.

A rheumatic type of facial neuritis, known as Bell's palsy, is the most frequent affection of the facial nerve. Its etiology is usually exposure of the face to severe cold, a chilling draft or such as driving a closed automobile with only one window open. A pre-existing focal infection may furnish a predisposing factor.

The well-known symptoms of this distressing nerve lesion may appear after a short period of numbness or tingling or without any premonitory symptoms. Since the facial nerve carries no sensory fibers, there is usually little pain, but the sudden onset often disturbs the nervous equilibrium of the patient seriously, especially in women. The uncertain prognosis offered by the average physician, who is unfamiliar with electrodiagnosis and of the means of relief by electrotherapy, only adds to the distress of the patients.

Rationale of Early Treatment.—The effectiveness of early treatment in rheumatic facial paralysis is explained by the anatomical condition of the facial nerve. It has been shown that exposure of a side of the face to the play of a current of air (draft) leads to a rapid evaporation from the skin, with an accompanying superficial vasoconstriction and a simultaneous deep-seated congestion. As a result, the neurilemma of the nerve trunk becomes swelled and impinges upon the neuroaxial fibers because of the non-yielding bony constriction of the stylomastoid foramen. Cobb and Coggeshall[2] state that exposure of the facial nerve brings on an edema that blocks the stylomastoid foramen and presses on the facial nerve. This etiology offers the possibility of a quick absorption by suitable physical measures, as has been amply proved by clinical experience and it also explains the number of spontaneous recoveries within a few weeks, with absence of the reaction of degeneration in the so-called light cases. On the other hand, in untreated or originally severe cases, secondary involvement of the nerve fibers occurs due to continued pressure and, according to the extent of the nerve degeneration, a condition lasting from a few weeks to a year and leading possibly to permanent atrophy of some of the smaller muscles may ensue.

On the basis of these facts, the immediate application of "decongestive" measures in cases of Bell's palsy seems rational and the author's favorable experience with cases treated from the onset makes it evident that the former dictum, that no treatment and especially "no electricity" should be administered during the so-called painful period, is obsolete. Other clinicians report similar experiences; the variety of physical measures recommended for early treatment of Bell's palsy include thermal, mechanical and electrochemical agents. The fact that they all have been reported on favorably can signify only that when employed in sufficient dosage and frequency they all accomplish their main object, the improvement of local circulation with the subsequent relief of pressure from edema.

Treatment should begin in all cases with a superficial thermal measure such as the radiation from a small luminous heat or infrared generator. An exposure of from twenty minutes to one-half hour results in improvement of the circulation and nutrition and also serves to relieve pain if present. The comfort given by diathermy is even more marked: one smaller air-spaced electrode is held close to the affected side, another larger electrode over the normal side. The treatment drum method is also convenient. Long-wave diathermy application with contact plates is more difficult.

Thermal measures bring about "decongestion" by influencing circulation and metabolism of the soft structures in the area treated.

Electrochemical measures are recommended by clinicians here and abroad. The late Granger[4] lauded galvanism from the negative pole, at a strength of 5 to 15 milliamperes for twenty minutes. For pain he recommended ionization with 2 per cent sodium salicylate. After galvanism Granger advocates electrical stimulation with the interrupted galvanic current from the very beginning. Bourguignon and his followers are quite enthusiastic over ionization with a 1 per cent potassium iodide solution, applied from the negative pole not only to the side of the face but also along the external auditory canal through a cotton pack soaked in the solution. It is claimed that this method acts more directly on the facial nerve. It is a justifiable assumption that electrochemical interchange of fluids and their ionic contents will result in an effect similar to that of thermal measures and thus help in the absorption of the local edema.

Mechanical measures for early treatment comprise the static wave current, the monoterminal high frequency or Oudin current, and manual massage. The static wave current when available is applied with a crescent-shaped electrode in front of the ear and offers the advantage of a two-fold effect: rhythmic mechanical action on the soft tissues underneath the electrode and electric stimulation of all muscles supplied by the facial nerve. The Oudin effleuve, furnishes a combination of gentle mechanical action, mild heating and some counterirritation, without muscle stimulation.

It is generally agreed that electrical stimulation is a useful measure in all cases of facial paralysis, but there appears to be a difference of opinion whether it is to be used from the beginning or only in a later stage. As long as we accept that electrical stimulation is useful in maintaining physiological activity in weak and paralyzed muscles and that when correctly applied it cannot do harm, there is every reason why carefully graded stimulation should be employed in all cases from the beginning. Besides its physiological effect it helps to bolster the patient's morale, which is usually badly impaired by the dramatic appearance of a "crooked face." Clinicians using the static wave current from the beginning report great satisfaction from the combined use of decongestion and electrical stimulation.

The often repeated effect in clearing up the condition in a comparatively short time by early treatment can be explained by the removal of the inflammatory infiltration around the nerve trunk. In such cases testing of the RD after eight days of daily treatment will show its absence and the presence of the normal type of faradic response.

As stated in Chapter VII the electrical reactions will not show any appreciable change during the first eight days of facial paralysis. If the patient reports for treatment only eight days or later after the onset of the disease the first step is to test for the reaction of degeneration. If there is no RD the prognosis for early recovery is favorable, and treatment should be instituted with the same technique and gradually changed from daily treatment to every other day until full voluntary function returns. In cases of partial or full reaction of degeneration, individual motor point stimulation should begin immediately by a low-tension and low-frequency current—such as the interrupted galvanic, slow (galvanic) sinusoidal, or a modulated alternating current. It is doubtful whether return of function is ever speeded up by such treatment; on the other hand it is likely that it counteracts atrophy of the smaller muscles, just as atrophy of the small intrinsic muscles of the hand in nerve injuries may be combated by suitable electric stimulation.

After the electrical treatment gentle stroking hand massage is applied for five to ten minutes and the patient is instructed to exercise the facial muscles as much as possible, preferably in front of a mirror. It is important that the sagging of the affected side of the face be prevented as much as possible from the onset. An adhesive strap may be used overnight to pull up the face toward the zygoma or a suitable elastic strap may be worn around the affected side; a padded fish-hook inserted into the angle of the mouth and fastened around the ear may serve also.

As soon as there is response to the faradic current, gentle faradic surges or the interrupted sinusoidal current may be used. It has been claimed that the occurrence of late secondary contractures in severe cases is due to the use of the faradic current. As long as the current is applied with a gentle technique and the muscles are not fatigued the treatment can cause no such effect. A sign of overstimulation would be if on subsequent treatments, using the same technique, more current should be needed to elicit the same response.

Voluntary exercise is most desirable for restoring muscle tone and should be used as early as possible.

Many patients complain of irritation of the eye on the paralyzed side. The eye is best protected by wearing glasses on the street. Frequent washes with boric acid lotion and closing the eyelid passively at frequent intervals may relieve the unpleasant tearing.

Through the management as outlined and with the general condition of the patient receiving careful attention at all times, most cases of peripheral facial neuritis will recover within a period predetermined by electrodiagnosis.

In facial paralysis due to a central or focal lesion or to traumatism the ultimate prognosis depends on the elimination of the cause; the local treatment is practically the same; perseverance and careful attention to all factors offers the best chance for recovery.

In early cases of *traumatic* and *toxic* facial paralysis careful stimulation through the nerve also is indicated. It need not consist of more than a few contractions at first. In all cases in which irritability through the nerve is maintained, electric treatment may be continued only until it can be replaced by voluntary exercise.

Treatment by physical measures should be continued as long as there is room for improvement. This may mean a period anywhere from four weeks to a year. The electrical reactions serve as an important guide for continuing or discontinuing treatment, especially in traumatic cases. Regarding *ear cases,* Nühsman[7] states that if facial paralysis lasted two months or longer and there is complete lack of electrical response of the nerve and of all muscles, the possibility of restitution is highly doubtful. Most otologists are inclined to continue conservative treatment even in case of known severance of the facial nerve, as long as electrical reactions are present. The facial nerve has a very marked power of regeneration. In cases at a standstill or hopeless, well-tried methods of plastic repair are available.

Brachial Neuritis.—The diagnosis of this lesion is often unsatisfactory. The generally accepted signs are diffuse pain, disturbance of sensation, tenderness of nerve trunks and weakness or paralysis of muscles definitely limited to a certain nerve or group of nerves. The present tendency is to attribute diffuse pain not following typical nerve distribution to radiculitis or to a lesion of the spinal nerve roots embracing the part of the nerve extending from the anterior horns of the cord to the emergence of the nerve through the dura mater. Inflammation or pressure within the interspinal segment, due to trauma, arthritis or focal infections, is often a causative factor. When the nerve root is included in the area of treatment the results are often much more satisfactory, thus supporting the theory of radiculitis as an etiological factor. Among other etiological factors are traumatism around the shoulder leading to organization of extravasated blood between the shoulder muscles and in the axilla and through contracture about the nerves with subsequent pressure. Pressure of the head of the humerus upon the brachial plexus in stoop shoulders may also be a factor.

Fig. 303.—Galvanic treatment to right upper extremity through medium of local hydrogalvanic bath. Two tanks holding the two arms have the same polarity, while shoulder pad serves as active electrode (Courtesy of Teca Corporation.)

The general principles of physical treatment are those previously described. Short-wave diathermy if applied with one pad on the side of the neck opposite to the affected area, the other along the upper arm or more distal. A pancake coil may also be applied against the shoulder. The monoterminal current subsequently applied along the entire area will add to the relief. Ultraviolet radiation to the degree of mild counterirritation may be also helpful. In chronic cases with adhesions and thickening, prolonged administration of galvanism or iontophoresis with vasodilating drugs is recommended and radiotherapy is also extolled. Galvanism may be administered with the hand in a water-bath and one electrode over the cervical region. (Fig. 303.)

Sciatic Neuritis.—The sciatic nerve is the longest nerve in the body and in its long course from the lumbo-sacral vertebræ to the heel and the sole of the foot may be subject to various kinds of lesions, traumatic, mechanical, toxic and infectious. The definite diagnosis of sciatic neuritis must be based on careful investigation of every portion of the nerve, location of typical points of tenderness and on the corroborating evidence of the positive Lasègue's test: flexing the thigh on the pelvis with the leg extended—which manipulation stretches the sciatic nerve and brings about characteristic pain.

In *acute* sciatic neuritis mild diathermy is the measure primarily recommended. In very painful cases it must be administered in the patient's home or in the hospital. Diathermy should be preceded by a fifteen-minute application of luminous heat from a powerful source, a 1500- to 2000-watt lamp, in order to bring about hyperemia of the limb and lower back. Stroking massage or the Oudin current applied over the course of the nerve may be added for gentle counterirritation. In a report from the Mayo Clinic[3] on the treatment of sciatica by various combinations of treatment the best result in ambulatory cases—85 per cent complete relief—was accomplished by the combination of epidural injection (40 to 60 cc. of a 1 per cent solution of procaine hydrochloride), a belt and diathermy. In bed cases, 85.7 per cent were completely relieved by the combination double Buck's extension, diathermy, epidural injections, intravenous injections of foreign protein and elimination of foci of infection.

As in other forms of neuritis, galvanism may serve as an alternate treatment and may be employed either by the longitudinal or the transverse technique. In the former a moist pad electrode, large enough to cover the lumbo-sacral region and most of the buttock of the affected side, is used; the foot is enveloped in a thick layer of wet gauze up to the upper third of the leg and a metal pad is placed under the part covering the sole of the foot. It makes no difference in which direction the current travels. The principal effort is directed toward applying a current of a strength up to 20 to 30 milliamperes at each session. A foot bath may be used also as one electrode. The transverse method consists of applying two long narrow electrodes opposite and equidistant to each other on each side of the entire lower extremity, with the interposition of a thick layer of gauze or bath toweling, well soaked in saline. Kowarschik administered up to 100 or more milliamperes by this method, from thirty to fifty minutes, and claims that his results were quite satisfactory. As in diathermy, treatments are given first daily and then every other day. The author has recently employed ion transfer with mecholyl in selected cases and found this method more effective than simple galvanism. In a bed-ridden patient and with a limited apparatus, prolonged applications of luminous heat or infrared rays may give marked relief. Starting from the lumbo-sacral region an area corresponding to the range of the lamp is exposed for one-half hour and then the lamp is moved over the next area. Counterirritation by ultraviolet is also applicable in some cases.

In *chronic* cases of sciatic neuritis the characteristic symptoms are dull aching and paresthesia instead of the continuous sharp pain in acute form and possibly also atrophy and weakness of the leg muscles. These symptoms are the result of a true fibrositis, degenerative processes in the nerve and adhesions and pressure in its sheath.

Thermal measures followed by active mechanical measures for the breaking-up of adhesions are indicated for this condition. The surging faradic current or the interrupted sinusoidal applied with either the longitudinal method or with the individual motor point technique will exercise muscles and assist in breaking-up adhesions. The static wave current followed by vigorous sparking over the points of special tenderness is very effective. Irradiation of the spinal nerve roots by roentgen-rays has been extolled and may be worth trying in resistant cases. The prognosis is more favorable in early cases when diathermy quickly produces a subjective feeling of heat in the affected leg. Patients with defective heat sensation offer a less favorable prognosis on account of the organic changes in and around the nerve. Lack of heat response contraindicates diathermy or short-wave diathermy. In cases which do not respond well, efforts should be made to better locate the seat of inflammation and treat it directly. In some of these patients counterirritation by vigorous short sparking from the Oudin terminal or sun-burning doses of ultraviolet irradiation may help. General thermal measures in the form of electric light cabinets or regular fever treatments may bring about a favorable turn in particularly resistant cases.

Radicular pain due to pressure upon nerve roots has received added study recently. In discussing the treatment of back injuries Wentworth[11] states that one may accept that the posterior primary division of the spinal nerve winds closely over the ligamenture of the articulation, and that any inflammation of the joint may institute radiating pain; but that there is direct pressure upon the nerve roots appears improbable; there would seem to be ample space for the nerve in any spinal position. Others believe that the occurrence of neuritic pain suggesting spinal arthritis is often due to segmental neuritis resulting from compression of the nerve roots by narrowing of the intervertebral foramina. In a number of the cervical cases the application of head traction or at least suitable bracing is essential. Diathermy is useful for relief of pain in many cases.

Meralgia Paresthetica.—Meralgia paresthetica is a localized neuritis of the external cutaneous nerve of the leg manifesting itself by a constant burning sensation and hyperesthesia along the outer surface of the thigh. Its cause is a fibrosis, pressure on the nerve as it passes through a fibrous tunnel of the fascia lata. Radiant heating followed by mild Oudin application usually relieves this condition in a few treatments.

Trifacial Neuralgia.—All true cases of tic douloureux are most painful. The most resistant form of nerve irritations are due to a lesion of the Gasserian ganglion, situated at the base of the skull and practically inaccessible to any form of treatment, save surgery. There are conflicting views as to the pathology in the Gasserian ganglion; one point of view suggests arteriospasm, angioneurosis, brought about by some sympathetic unbalance. Yet, as Turrell stated the attempt to corroborate this seemingly rational view by the results of treatment by diathermy fails. Theoretically, it should be able to relieve an arterial spasm even at considerable depth, yet in the majority of cases of trifacial neuralgia diathermy and even the more penetrating short-wave diathermy do not seem to help.

Typical cases of tic douloureux are characterized by excruciating attacks of pain and spasm of sudden onset and without apparent cause or following a very slight provocation, like a slight touch or blow of air. The sleep of these patients is usually not disturbed. Cases with referred trifacial pain, peripheral neuritis of some of the branches, may be due to a lesion of the teeth, infection of the jaws or jaw bones, as osteitis, or in the sinuses. The pain in such cases is less paroxysmal, more constant and often disturbs the sleep. Careful differential diagnosis based on competent dental, nose and throat and neurological examination is essential. Cases of peripheral neuritis can be more rationally attacked.

The galvanic current is successful in some cases and it has enabled the author to comfort some patients in whom the painful alcohol injections failed to give lasting relief. The technique of application consists of using a special crescent-shaped pad electrode covering the entire facial distribution of the nerve, with suitable indentations for the eye and mouth; a large dispersive pad electrode may be placed over the chest or back of the patient; this offers, to the greater part of the current, a path outside of the skull. The active electrode may be connected to the positive pole, and a current strength from 10 milliamperes working up to a maximum of 40 or 50 should be aimed at. The good results obtained by intensive galvanization are attributed by Turrell to a counterirritating skin effect, desensitizing the receptors in the affected area.

Symptomatic relief by "rapid sinusoidal" current—the 60 cycle alternating current—controlled by a rheostat has been reported by Ulanski.[10] Only a few minutes' stimulation is applied by a small active electrode over the painful areas.

Ion transfer with quinine or aconitin solution applied from the positive pole has also been recommended. The static brush discharge may give relief over particularly tender areas. Ultraviolet irradiation has been unsuccessful. Roentgenologists claim results from roentgen-rays and they may, therefore, be tried. Modern surgery in the form of a section of the dorsal root instead of the barbarous and extremely dangerous extirpation of the ganglion is being employed as an ultimate resort with complete success in many cases.

Intercostal Neuralgia.—The most frequent cause of severe intercostal pain is the inflammation of the spinal ganglion in herpes zoster; traumatism, exposure or a local or general inflammatory process (pleurisy, pneumonia, arthritis or myositis) are among the other causes. Physical measures serve for relief of pain and for shortening the course of the condition.

Diathermy combined with ultraviolet is clinically the most effective measure next to the static brush discharge, which, however, is not so readily available. In diathermic treatment one electrode should be placed over the entry of the affected intercostal nerves at the side of the spinal column; the other electrode should be in front at the site of the greater pain. An inductance coil may be also placed over the entire painful area. Diathermy may be followed with mild sparking from the Oudin terminal. Much more satisfactory is the application of ultraviolet radiation to the site of the pain, to the degree of a mild dermatitis. This combined treatment should be repeated daily until there is marked improvement. However, severe cases of true ganglionitis may take many weeks until combined use of medicinal and physical measures brings final relief.

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CHAPTER XXIX

AFFECTIONS OF BONES, JOINTS, MUSCLES AND TENDONS

Traumatic Conditions. General Considerations. General Pathology. Objects and Forms of Physical Treatment. Contusions. Injuries of Joints and Muscles. Strains. Sprains. Dislocations. Traumatic Arthritis. Stiff Joints. Injuries of Bones. Fractures. Amputations. Back Injuries. Coccygodynia. Affections of Bones and Joints. Osteomyelitis. Tuberculosis of Bones and Joints. Affections of Muscles. Acute Myositis. Chronic Myositis. Volkmann's Ischemic Contracture. Affections of Tendons and Bursæ. Tenosynovitis. Bursitis. Shoulder Conditions. Miscellaneous Surgical Conditions. Adenitis. Burns. Foot Conditions.

TRAUMATIC CONDITIONS

General Considerations.—The value of physical measures in the treatment of traumatic conditions is well established. Their correct employment however entails the observation of certain prerequisites and safeguards.

1. There must be a definite diagnosis of the local injury as well as of the general condition of the patient before physical treatment is ever instituted.

2. The initial surgical work must be the very best. No amount of skilled physical treatment can compensate for poor surgery.

3. Physical treatment must be properly indicated and must never be applied to the neglect or exclusion of important or superior medical or surgical procedure.

4. The physical treatment best suited for the condition must be selected and applied with intelligence, skill and diligence. There must be a sufficient variety of available measures.

5. Physical treatment should cease when the patient can do for himself what the treatment is designed to help him perform. Adequate records must be kept from beginning to the final check-up.

6. There must be complete coöperation between the surgeon and physical therapist. Physical treatment must be instituted from the time of admission, for it is just as grievous to indulge the patient in continued unnecessary treatment as to neglect giving him the benefit of treatment early in his disability. Periodic consultations are essential.

General Pathology of Injuries.—In recent injuries there is extravasation of blood and lymph from torn vessels and capillaries, edema from increased transudation of lymph and there may be tearing of ligaments, rupture of muscles and tendons or injury to cartilage or bone. The primary indications for treatment are the stopping of hemorrhage, overcoming of shock, prevention of infection, uniting of broken surfaces and provision of physiological rest for undisturbed healing.

Chronic disability is maintained by the fact that the body forces are not always successful in removing unaided the products of recent traumatism, and in combating the subsequent infection. Passive hyperemia is caused by damage to vessel walls and the irritation of vasomotor nerves; its final result may be structural changes such as permanent enlargement of small vessels, increase of connective tissue and later fibrotic induration. Adhesions are caused by the organization of "coagulable" lymph exuded following the injury and formed during the process of inflammation and repair. In the early stages this granulation tissue holding together the adjoining surfaces of muscles, tendons and fasciæ can be easily separated. In the later stages the newly formed blood-vessels disappear, the new tissue becomes fibrous and contracts; bands form which irregularly bind together adjacent surfaces, causing limitation of motion and pain by pressure or by stretching of nerve endings. Muscle atrophy may be caused by disuse, by interference with circulation, by disease of adjacent joints or by injury to the nerve supply. In most cases of injury a vicious circle is established, the injury itself causing a diminution of blood supply and inactivity and the subsequent loss of muscle action resulting in further loss of tone and atrophy.

For many years the routine management of recent traumatism consisted of immobilization in order to provide undisturbed healing. The three principles of Thomas for treatment were: rest, test of recovery by tentative use in splints and finally, natural use. This procedure ignored the fact that for the repair of an injury efficient blood supply is necessary and that rest itself promoted the organization of the extravasated fluid and induce formation of intra- and perimuscular as well as periarticular adhesions. In immobilized extremities there also develops an early atrophy of muscles. The present day tendency in treatment of recent injury is to provide immobilization only as long as necessary for the proper coaptation and adherence of broken surfaces or torn ligaments for it is now generally recognized that the neglect of soft tissue damage is often the principal cause of delayed recovery and subsequent discomfort.

Objects and Methods of Physical Treatment.—The object of physical treatment in injuries will vary with the type of injury and the individual in whom it occurred. Just as general surgical principles must be maintained in the varied types of injuries while the treatment in the individual may vary widely, so must physical measures be adapted to the individual and must include an armamentarium sufficiently wide to be used effectively. Generally speaking physical treatment may have as its object: in acute cases, the acceleration of the process of repair and restoration of function, the promotion of absorption, the prevention of adhesions, the relief of pain and the relaxation of muscle spasm; in chronic cases, the removal of inflammatory products, the softening of adhesions or scar tissue, the improvement of nutrition in muscles and the maintenance or increase of mobility in joints.

The general scheme of the treatment of recent injuries is as follows: The first requisite is an accurate diagnosis as to the nature and extent of injuries. If the injury does not demand complete immobilization the immediate application of gentle stroking massage by the physician to the periphery of the traumatized area, will reflexly speed up the circulation, hasten the dissipation of the edema and relieve pain. A short cold application in the form of an ice-bag or an iced compress exerts a vasoconstricting and pain relieving effect and is useful in the immediate treatment of contusions and hematomata. After the checking of edema and swelling an elastic bandage or strapping may be applied; the injured part may be elevated and kept at rest.

With the passing of the acute stage *thermal measures* should be employed for the improvement of circulation and the relief of pain and as an introduction to suitable mechanical measures. In all subacute and chronic injuries, heat is one of the principal means for speeding up the process of repair and to comfort the patient. Its various forms are selected according to the location and extent of the injury. Radiant sources of heating serve conveniently for affecting the skin, subcutaneous tissue and the superficial layers of muscles, while diathermy and short-wave diathermy serve more efficiently for heating deeper structures, especially joints and bursæ.

The modern hot whirlpool-bath offers a combination of heating with hydromasssage. It is most effective as a circulatory stimulant in fractures immediately after removal of splints or cast, in indolent ulcers, adherent scars and peripheral nerve lesions.

Mechanical measures such as massage, active and passive exercise and electrical stimulation of muscles and tissues, may be employed for combating the immediate effects of trauma; edema, exudation and muscle spasm, or its sequelæ: adhesions and stiffness. They may also serve to exercise weak or paralyzed muscles, and for relieving pain by reflex action or by removing pressure. As a rule mechanical measures work best when preceded by suitable heating.

Massage is the simplest and most popular mechanical agent, requiring only a pair of skilled hands, directed by a trained brain. Early application of relaxed passive movement or of exercising electrical currents will act as a preventative of stiffness, fibrosis and muscular atrophy. Later, careful active movements are instituted. Active exercise is the most desirable for re-educating wasted muscles and, for increasing the range of joint movement and for promoting muscle coördination. Resistive exercises enable localization of effects to certain joints and muscles. Passive exercise is a dangerous procedure and must be reserved for special conditions and expert hands.

Electrical currents of low frequency, such as the surging faradic, serve for stimulating weak muscles without moving the joints upon which they act; they also serve in other forms for maintaining some of the functions in fully paralyzed muscles. Electrodiagnosis is at times indispensable for diagnosis and prognosis in nerve lesions or simulated paralysis. The static wave current when available offers a useful combination of muscle exercise with gentle tissue massage.

Electrochemical measures in the form of the galvanic current or chlorine ion transfer may serve for promoting absorption of small scars. Ultraviolet radiation may help locally in some infections, in burns and for stimulating epithelization.

INJURIES OF JOINTS AND MUSCLES

Contusions.—The typical signs of a contusion are swelling, ecchymosis, discoloration of the skin due to hemorrhage, local tenderness and limitation of motion. A diagnosis of contusion is not justified until every other possible lesion has been eliminated. Immediately following the injury nothing will give so much relief from pain as cold compresses or an ice-bag; the contraction caused by cold will also tend to arrest hemorrhage. After twenty-four hours, hot moist applications or exposure to radiant heat may be started; the latter should be kept up for one-half hour every two or three hours. Hot compresses are less desirable because they dry rapidly. Immersion in hot water keeps the part hanging down, whereas elevation is more important than heat. If there is marked local edema, gentle stroking massage should be given for a few minutes after heating.

Local tenderness not fully relieved by these measures may be further comforted by a ten-minute application of the Oudin current or high-frequency stroking (Chapter XI). Careful passive motion for a few minutes by the operator and a few minutes active motion by the patient should end the treatment, which is to be repeated at first once daily; later every other day, until the condition has fully cleared up.

Strains.—Excessive use—as a rule stretching—of a muscle or a joint without a tear or displacement is known as a strain. Muscular strain is suspected when particular pain is elicited by contraction of a specific muscle against resistance and when localized tenderness is present over this muscle or its tendon. Smart[22] states that even a slight strain may result in a slackness of the injured muscle and a loss of its tone and interfere early or later with the mechanics of the joint upon which the affected muscle or muscles act. Such a condition is often overlooked because there appears to be little the matter with the joint except a feeling of weakness and insecurity. Smart states that this constantly occurs as the result of the injury of the knee-joint and if a knee presenting undue mobility is carefully examined the atonic condition of muscles will be readily noticed.

In severe muscle strain a subcutaneous wound of more or less severity accompanies the loss of tone and contractility; there is extravasation of lymph and blood, and considerable restriction of motion. In the later stages adhesions are formed which are highly sensitive; in addition there may be a protective spasm of the neighboring muscles opposing any attempt to drag on the adhesions. The final result may be fixation and stiffness of a muscle or group of muscles.

Immediate treatment should be applied as described under contusions; this is followed by the artificial contraction and relaxation of muscle advocated by Smart. This treatment aids recovery of muscle tone, promotes absorption of the effusion, directly stimulates free circulation of blood in the injured part and its neighborhood and above all prevents the formation of adhesions around the muscles and tendons. Massage and active exercise serve as important alternates of treatment.

Sprains.—A sprain of a joint implies primarily a tearing of ligaments, but may also involve injury to the periosteum, muscles, tendons, blood-vessels and supporting soft tissues. The typical signs are swelling, pain, increased or abnormal mobility of the joint when there is damage to its ligaments and localized tenderness. The pathological signs will vary greatly according to locality. In some, as in the ankle, more of the stress is taken on by the ligaments; in others like the shoulder, damage affects the muscles more. The key to recovery, however, in each of these cases is the release of the effusion and the completeness and speed of its absorption.

Every joint injury diagnosed as a sprain must receive a radiographic examination. Severe sprains at times must be immobilized and in most cases elastic pressure in the form of bandaging or strapping is applied to prevent or limit effusion.

Treatment.—Besides the use of external forms of heating the early use of diathermy has proved especially effective for the reduction of swelling and promotion of absorption; it should be followed by either graduated muscular contraction or massage.

The immediate stimulation of all involved muscles by a surging faradic current in uncomplicated sprains is considered by Laquerriere[15] more effective than any other form of physical treatment. He bases its rationale on the similarity of reported quick recovery of sprains after an injection of a local anesthetic and early motion. Its further advantage is that with portable small apparatus it can be employed at the bedside in sessions of ten minutes several times a day. Smart[22] reported similar experiences and the author can corroborate these.

Correctly applied massage will help considerably to speed up recovery. It should begin with gentle stroking above the site of the injury, with the whole limb in a position to relax all muscles. This procedure aims to restore vasomotor tone and prevent further swelling. After treatment firm bandaging or strapping is to be applied. At subsequent treatments deep stroking and kneading may be used to dissipate the effusion. Careful and limited passive movements are given to the affected joint, while those distal to the injury are freely moved. Treatment should be given daily from ten to thirty minutes and gradually increased, while the support of bandaging or strapping is gradually reduced.

The joints most frequently sprained are the ankle, knee, elbow, shoulder and wrist, more rarely the hip and the sacro-iliac joint. In *ankle joint* injury the first concern is to reduce the swelling; cold application of half hour or so in a foot bath or by an ice-bag, followed by adhesive plaster strapping, so applied that it approximates the torn ends of the ligaments. Ewerhardt[8] strongly recommends immediate walking in uncomplicated cases, for muscle contraction and joint motion accelerates the circulation and hastens resorption more than the use of heat alone. The new techniques of short-wave diathermy enable early heat treatment without the necessity of removing the strapping.

Knee injuries of some severity require immobilization in a cast, followed by use of heat, massage and exercise. Mild sprains of the *shoulder* usually respond well to adhesive tape support extending over the joint and from there to the anterior and posterior wall of the chest, with the arm supported in a sling for a week. Sprains of the *wrist* may require immobilization during the acute stage with moulded volar plaster splint which may be removed daily for use of heat and massage.

Mild sprains of the *elbow* may be treated by early application of cold compresses to prevent effusion, followed by a compression bandage applied with the elbow in 90 degree flexion and supported by a sling. Later the whirlpool bath may be used. Manual massage should be avoided in traumatized elbows, especially in younger people on account of the tendency to promote the occurrence of the condition known as myositis ossificans, formation of extensive calcifications.

In the elbow single or recurrent muscle exertion often brings about another typical traumatic condition, known as "*tennis elbow,*" although it may occur in baseball pitchers and others. Its signs are tenderness usually localized over the internal lateral ligament and the extensor muscles, swelling about the elbow and pain on extension of the elbow and supination of the forearm. The pathological changes underlying this condition have been variously described as an arthritis of the radiohumeral joint and as a bursitis of the radiohumeral bursa. Hansson and Norwich[11] described it as an epicondylitis due to a periosteal tear and a myofascitis of the extensor muscles originating from the external epicondyle. The treatment recommended consists of: (1) physiological rest by a light cock-up splint to the forearm such as used for wrist-drop, and held by two straps; this enables the patient to continue all flexion activities of the hand; (2) diathermy for thirty minutes to the extensor muscles with a semicuff applied over the upper half of the extensors and the other electrode under the flexor surface; this is to be followed by ten minutes massage. In resistant cases surging faradism or the static-wave current may be applied over the extensor muscles.

Dislocations.—In a dislocation there occurs a rupture of the joint capsule, usually at its weakest point. After the displacement is reduced, we are dealing essentially with an arthro-chondrosynovitis, and a wound in the capsule. The rest of the capsule and the ligaments are usually intact and only certain motions may cause a redislocation.

Perhaps the commonest joint dislocated is the shoulder with anterior dislocation as the most frequent type. After proper reduction the only motion that will result in redislocation is abduction and extension. If these be prevented there is no possibility of the joint redislocating. A simple sling should be worn for a few days and the patient advised not to make attempts at the motions which might cause redislocation; there should be no delay in starting other motions and physical therapy which will promote the rapid absorption of extravasated blood and hasten the repair in the soft tissues surrounding the joint.

Dislocations of the *elbow* usually are posterior. After reduction, cold applications are followed by use of a compression bandage. Some surgeons employ acute flexion with the wrist in supination, and others favor right-angle flexion and a neutral pronation-supination position. "Muscle setting" exercises may be instituted while the arm is in the sling. As soon as the sling can be removed temporarily, the arm may be placed in the whirlpool bath and active motion encouraged to the point of pain. When the arm is removed from the sling, exercises should be continued.

In uncomplicated dislocation of any joint which has been reduced physical therapy should start on the day of the accident. If this is done much time will be saved in the restoration of function.

The muscles acting upon the joint are usually damaged and may immediately lose their tone and suffer further damage if rest is enforced. Heat measures, graduated muscle contractions are the standbys of treatment; early massage in the form of effleurage promotes the absorption of effusion and relaxes muscle spasm. Gentle friction prevents the formation of adhesions. During passive movements the injured joint must be well supported by the operator's hand.

Traumatic Arthritis.—Traumatic arthritis may be caused by: (1) a single severe injury to the joint cartilage; (2) repeated mild injury to the joint cartilage; (3) disorganization of the mechanics of a joint; (4) abnormal function in a joint on account of bony deformity so that use brings about repeated injury to the joint surface; (5) gradual deformity in a joint as a result of abnormal pressure (Key[12]). The pathological changes resemble those in osteo-arthritis; there is degeneration of the articular cartilage, fibrosis of the joint capsule, production of new bone and cartilage around the articular margins and hypertrophy of the synovial membrane. The chief characteristics of these changes are that they occur only in one joint, the joint which has been subjected to injury.

All clinicians agree that rest is the most important initial physical therapy measure in this condition; after the acute symptoms have subsided, gradual mobilization, support by elastic or leather and protection from strain by correcting posture are advisable. Smart[22] states that it has been laid down as a general rule, that when a joint is restricted in movements in all directions, the joint should be rested and not manipulated, because such limitation usually means that the joint is or has been in the state of acute arthritis. If movements are only limited in some directions, the joint may be manipulated with due care.

Diathermy is the most effective measure to improve local circulation and speed up the subsidence of inflammation, and serves as an introduction for active and passive movements. Daily treatments are indicated. Graduated muscular contractions or massage should be also systematically employed.

The final prognosis in traumatic arthritis depends upon the cause of the condition, the amount of use to which the joint has to be subjected, and whether or not the abnormality incident to the injury can be corrected. In younger persons, especially men, the chances for full recovery are usually much better.

Stiff Joints.—Many instances of joint stiffness following sprains in which rest and lotions were used are due to the immobilization and not to injury. Likewise, the flabbiness and weakness of muscles around a joint is due to reflex atrophy; these muscles usually being supplied by the same nerves as the joint. The early use of appropriate physical measures may prevent most ankylosis.

If ankylosis is once established before instituting treatment one must make sure that there is no real bony block present, and, furthermore, that adhesions exist only between the articular ends of the bone and the capsule or that only the capsule is adherent and contracted. When there is serious destruction of cartilage or marked deformity of the adjoining joint surfaces physical measures do not promise the best results.

The principle of treatment in suitable cases is to limber up the fibrous, contracted tissues by a thermal measure, preferably, diathermy, or luminous heat or a hot whirlpool bath as its substitute, and follow this by active exercise, massage and manipulation. Graduated muscular contractions by surging faradic or the static-wave current applied with a moulded electrode over the joint will often help by their gentle stretching and exercising effects on muscles and periarticular tissues. Appropriate massage movements are most helpful in stretching adhesions. After preliminary warming, deep stroking is used at first, followed by deep kneading of the muscles above and below the joint. Friction movements may be applied over the joint and finally passive movements and resistive exercises are added. A fairly severe reaction may follow such heavy massage and in such cases temporary rest and immobilization has to be applied.

INJURIES OF BONES

Fractures.—The modern treatment of fractures recognizes that the pathological change present is a solution of continuity of a bone situated in soft tissues which have been extensively damaged. Consequently the early employment of efficient physical therapy to the damaged soft parts will obviate the necessity of much of so-called after-treatment of fractures and it will be productive of much earlier and more complete functional and anatomical recovery.

In all three stages of fracture treatment physical therapy may be used advantageously.[5,17]

(1) *Prereduction Period.*—When fractures are accompanied by severe trauma to the surrounding soft parts with extensive hemorrhage, and reduction, open or closed, must be delayed for several days, heat and massage may improve the condition of the soft parts and permit application of definite treatment much sooner than would otherwise be possible. Murray[17] reserves such prereduction therapy primarily for fractures about the wrist and ankle seen after marked swelling has occurred and also in conjunction with use of traction suspension, whether by wire or by skin traction. Temporary skin immobilization, with the employment of elevation, constant low degree of heat by means of a blanket tent beneath which is an ordinary goose-neck lamp, light sedative massage, and one or more half-hour applications of the positive and negative pressure boot will frequently, within eight to twelve hours, result in such reduction and softening of the swollen and indurated part that manipulation can be far more easily accomplished because of the better recognition of bony landmarks.

(2) *Postreduction Period.*—In this period the aim is to remove the changes caused by the fracture and manipulative procedure. Murray employs elevation of the affected part, sedative massage of the whole extremity, constant low degree of heat by means of low milliamperage and muscle stimulation through some form of sinusoidal current. Wherever possible, this procedure is used in conjunction with counterbalanced suspension and active mobilization of the part by the patient. Such treatment prevents the organization of scar tissue in muscle and soft parts about vessels and nerves, in joint capsules and in tendons. It therefore minimizes the amount of functional limitation that has to be dealt with after the bone is healed. Under appropriate physical treatment a dislocated or fractured shoulder shows at the end of five days a soft clear skin, soft relaxed muscles, and freedom from pain and spasm. The saving in time of recovery is marked. The use of traction, or suspension or of hinged splints should enable employment of these measures from the very beginning, because they are most valuable during the first ten days. "Muscle setting" is a very important active form of voluntary muscle contraction which the patient may be taught to use even when the extremity is completely encased in plaster dressing. It consists of the patient "setting" or contracting actively the individual muscles of the injured extremity, without any actual movement of the joints; this is done several times a day and serves to increase circulation and maintain some of the muscle tone. In addition, all observing surgeons laud electrical stimulation for maintaining muscle function when used gently and painlessly and without causing spasm.

(3) *After-treatment.*—Unfortunately in the average case this is the period when physical therapy is most generally employed. It begins when bone healing has advanced sufficiently to allow discarding splints or apparatus.

Here physical therapy finds its greatest use in treating stiffness and atrophy following prolonged immobilization. If physical therapy is used intelligently during the first two stages, necessity for a prolonged third stage is eliminated to a large degree. In this stage all methods of treatment may be employed according to indications: whirlpool bath, paraffine bath, contrast baths, heat, massage and exercise.

In late stages of fractures physical therapy is only an adjuvant, full restoration of function depends chiefly on the efforts of the patient to regain the function by normal muscular activity. All physical therapy can do is to make it easier for the patient to carry out this task.

There is no injury in which *massage and exercise* can be used to greater advantage than in fractures. In fractures with great displacement massage and mobilization has to begin much later than in fractures with little deformity and the fragments held in good position. This is, of course, a matter for the attending surgeon to decide and as he assumes the responsibility for instituting the early treatment, it is expected that he supervise the treatment at first and issue definite instructions for the removal of splints, joint movement with the splint or without it and the type and duration of massage and exercise.

It is impossible to give other than general rules for each stage; the particular movements will have to vary with the type and location of fracture and the immediate response to treatment. The same considerations relate to the combination of active and passive movements with massage. Gentle surface stroking applied for a few minutes is always the first treatment in fractures. It should be preceded by mild external heating and, as a rule, no other massage movement should be applied until the knitting of the bony ends is firm. Great care must be taken to support the fracture. If it is possible a minute amount of motion should be performed in the joint distal to the fracture if it can be done without danger of displacement of the fracture ends. Hence this is preferably done by the surgeon at first. After six or eight days add light friction and careful passive movements in all neighboring joints and after ten days add kneading of muscles above and below the injury. After three weeks, treatment may include effleurage, pétrissage, frictions and active movements in neighboring joints.

After four weeks more vigorous massage may be employed with active movements. The patient must be encouraged to take movements by himself. Massage and other physical measures are a means to an end and the patient must be forced to realize this and work hard himself through work and exercise to assist in the recovery.

In *delayed union,* provided that there is no anatomical cause for it and there is a fair degree of fixation, diathermy is indicated for its effects on the local circulation and nutrition. The ordinary technique of transverse application at a comfortable tolerance should be used. Voshell[26] has seen encouraging results with short-wave diathermy applied through the plaster cast. There was no need of a supporting diet or viosterol in addition.

A favorable action of ultraviolet radiation on the consolidation of the callus by causing greater fixation of calcium salts in the fracture and more rapid evolution of the osteogenic process was shown in a series of controlled animal experiments by Racugno.[19] Irradiation was limited to the site of the fracture and employed in erythema doses.

Amputations.—An important function of physical therapy is the preparation of an amputation stump for early and efficient function. Heat, massage and early exercise are the means. Either whirlpool or contrast baths are used to improve the circulation in many cyanotic, cold and painful stumps and in those with low grade inflammatory condition or ulceration. Such baths are also beneficial when there is persistent edema or excessive periosteal connective tissue formation; they relieve the pain caused by poorly fitting prostheses at weight-bearing points. They should be used daily, and the patient may be instructed to use contrast baths at home with 2 ordinary pails. Massage can be started six or seven days after amputation if there is no infection. Following heat treatment, superficial and, later, deep stroking, kneading and friction are given in successive order and are followed in turn by passive exercise and stretching.

Early exercise of the amputated limb results in disappearance of the edema and further shortening of the period preparatory to fitting the artificial limb. Learning the mechanics of standing and walking with an artificial limb involves re-education in coördination of movement in the muscles of the stump and of tactile, muscular and joint sensation in the remaining part of the limb. After learning the mechanics of walking, the patient puts it into practice by walking between parallel bars used for support. When this has been mastered he is taught to walk with short steps using two canes and then to walk with longer steps using only one cane.

Back Injuries.—Back injuries form one of the most complex problems in present day traumatic surgery, partly because of the difficulty in accurate diagnosis of a condition largely subjective, partly because of frequent anatomical deviations from the normal which are not and never have been connected with the injury under consideration, and finally because of the complication of the picture by factors related to compensation in one form or another for injuries received while under employment or in some other accident. When confronted with a case of back injury, because of the vagueness and unreliability of many of the signs and symptoms presented, one needs to search for every bit of definite anatomical and pathological data one can elicit. Roentgenograms will ascertain or rule out lesions of the bony parts and a thorough clinical examination is indispensable for the recognition of pathological changes in the soft parts and in the patient in general. Two general types of back injuries may be differentiated: injuries with damage to the bony structure of the spine and those with damage limited to the muscular-ligamentous system. Schauffler[20] states: "For years sacro-iliac displacements or sprains have been overplayed. Then the honors were divided between lumbo-sacral and sacro-iliac sprains or they were simply said to be a low back sprain. Now the pendulum has swung far to the opposite side and many articles in recent literature claim that all these back pains are toxic." Shands[21] states that even with the help of roentgenograms, accurate differentiation between certain types of lumbo-sacral and sacro-iliac affections is often difficult. Physical therapy plays an important part in the management of back injuries; if its results are not as clear cut and dependable as in other types of injuries, this may be due to the often confused pathology and to the other factors enumerated.

There is general agreement that immediate and proper rest is most desirable for recovery of back injuries; it must be kept up from one to three weeks according to the seriousness of the injury. The back must be protected to avoid protective muscle spasm. According to Wentworth[28] the change due to injury is functional rather than anatomical. If muscle fibers or ligaments are torn or pulled away a new protective muscle function is immediately instituted, which persists until proper and adequate rest conditions are established. If not soon replaced by proper outside support, this spasm becomes a source of pain and disability in itself. In further physical treatment heat and massage are added; the author is using either long-wave or short-wave diathermy for thirty minutes or more, followed by massage, the surging faradic current or, if available, the static wave current and sparks.

In stubborn cases of chronic myositis iontophoresis with mecholyl may give satisfactory results; in others second degree erythema doses from an ultraviolet generator are helpful. Postural exercises, a careful régime of general hygiene, the alternation of rest and work are employed with success in selected cases.

In the manifold other types of back pain, traumatic and non-traumatic, there is a large field of applicability for physical measures, once the relative contributing influence of each factor has been recognized. A thorough review of this complex problem has been presented by Krusen.[14]

Coccygodynia.—Injuries of the coccyx often present a clear-cut picture, such as direct traumatism to the coccyx through a fall or blow, followed by acute pain and tenderness. At other times the symptoms are so obscure that the patients are considered neurasthenics. In these cases continued local pain and especially pain on movement or after sitting for a short time are suggestive. An examination of the coccyx through the rectum will show tenderness and slight manipulation may give instantaneous relief.

Surgeons have been prone to suggest operative removal of the coccyx on account of suspicious fracture lines or a questionable dislocation. Mock reports that roentgenograms of the normal coccyx in large number of cases show all kinds of variations in the position; he advises that all cases should receive careful physical therapy before operative removal of the bone is considered.

Thiele[24] reports that in practically all cases of coccygodynia spasm of the levator ani and coccygeus muscles can be accounted for as the cause of pain, while supragluteal pain and pain down the back of the thigh is caused by spasm of the pyriformis muscle. He found improvement in a large percentage of cases by massage of the muscles involved. Duncan[6] reports on successful non-operative management, consisting of improving posture—by having the patient sit erect and pull the buttocks in under the trunk—hot sitz baths—thirty minutes twice a day—local massage and finally steady but firm stretching of the coccyx posteriorly, in order to overcome spasticity and prevent adhesions.

The author has had most satisfactory results in a series of cases by diathermy applied with the technique described in Chapter XI. In three to eight treatments the pain and discomfort disappeared and patients were enabled to sit comfortably for the first time in many months.

AFFECTIONS OF BONES AND JOINTS

Osteomyelitis.—The treatment of acute osteomyelitis is a strictly surgical problem. In chronic cases there is a discharging sinus or more of them, a sclerosing osteitis, induration of surrounding soft parts, atrophy of muscles and stiffness in neighboring joints. Penetrating heat will improve the blood and lymph supply and it also relieves pain. Short-wave diathermy by the inductance coil or air-spaced technique is especially suitable for deep heating, because it overcomes the handicap of irregular bony surfaces or too extensive local processes preventing good electrode contact and position. On account of slow heating of bone a minimum of thirty-minute treatment periods are advisable. Luminous heat may be used simultaneously over the open sinus.

Ultraviolet radiation should be used systematically in all cases for improving the blood picture and to assist in overcoming calcium deficiency. Deep and tortuous sinuses furnish one of the few indications for the use of the local ultraviolet irradiation with quartz rods, introduced gently along the sinus tract for one to two minutes daily exposure.

The results of treatment show in the lessening of the discharge and odor, the gradual improvement of the condition of soft tissues and the filling-out of the sinus. Dressing with a plain petrolatum pack after each treatment is usually satisfactory. Other physical measures for overcoming the muscular atrophy and the stiffness of joints should be instituted according to the circumstances.

In tuberculous osteomyelitis ultraviolet radiation is indicated, together with general hygienic measures and rest.

Physical therapy in osteomyelitis must be used only in conjunction with proper surgical and radiographic control. Long continued and recurrent inflammation and drainage are usually associated with unremoved sequestra.

Tuberculosis of Bones and Joints.—Joint tuberculosis must be considered as a local manifestation of a constitutional disease and in its management heliotherapy or artificial light therapy is most valuable in conjunction with orthopædic and general hygienic measures, as stated in Chapter XIX. Following non-surgical régime restoration of function may occur in the synovial form of joint tuberculosis even in the presence of large effusions, according to Mayer.[16] Light therapy cannot produce new cartilage to replace that which has been destroyed, but it will help orthopædic treatment in fusing diseased surfaces especially when employed together with postural treatment. Surgical fusion and prolonged immobilization is a procedure to be considered chiefly in advanced joint destruction. Rollier's school is opposed to any surgery except in unusual instances, and claims that radiation heals, while surgery destroys. In the invigorating mountain atmosphere combined treatment by immobilization and heliotherapy may indeed achieve exceptional results.

While natural heliotherapy and the accompanying régime are most desirable, Mayer states that both mercury arc in quartz and carbon arc irradiations, employed as general and local exposures for prolonged periods of time, have proved aids in the treatment of bone and joint tuberculosis. The technique of irradiation is the same as that described with other forms of tuberculosis. With early exposures the joints or bones often respond with increase of the local swelling and pain and, if a sinus is present, increased secretion. These in turn subside. Small joints yield more quickly to treatment than large ones. The knee joint is refractory, and particularly obstinate are old fistulas of the spinal column, pelvis or hip. Treatment demands two years or more in many instances.

AFFECTIONS OF MUSCLES

Acute Myositis.—Acute myositis is characterized by an ache in the affected muscle, which is tender and is held rigid in order to prevent movement. It may follow exposure or a strain or it may come about in the course of an infectious condition, such as an attack of rheumatic fever. Pemberton attributes the condition to an alteration of the finer blood supply, as shown by a rather immobile capillary bed, in a state resembling vasoconstriction and responding inadequately to stimulation. According to the present conception of the rheumatic syndrome both acute and chronic myositis belong in the group of fibrositis and the main points of their pathology, diagnosis and constitutional treatment have been presented in Chapter XXVI.

Acute myositis has certain sites of predilection; among those are the shoulder, the lumbar region: lumbago, the intercostal muscles: pleurodynia, the posterior muscles of the neck: rheumatic torticollis. Local treatment in acute cases consists of the measures discussed under fibrositis, such as physiological rest and heat. This may be followed by gentle massage or the surging faradic current. If stiffness or spasm persist after such treatment surging faradism or a few static sparks usually help. This procedure, as a rule, effectively relieves both the pain and the spasm. Rest is essential during the acute stage.

Chronic Myositis.—In this condition the pain is duller and is particularly evident when the muscle is put into active use, while passive motion is usually free. In chronic cases this is an important differential diagnostic sign from arthritic involvement, where as a rule there is pain on passive motion. The chief pathological characteristic of chronic myositis is the tendency toward fibrosis. (See Chapter XXVI.) Inflammatory deposits form in the muscle, often near its tendon attachment and are demonstrable by definitely localized tender areas, with a palpable induration. Albee described this condition as myofascitis and considers it a local manifestation of a toxic condition.

The *treatment* of chronic myositis must as a rule be planned from the constitutional standpoint as well as from the standpoint of specific local relief. Local treatment is directed to the removal of the inflammatory products through the increase of circulation by luminous heat or diathermy and by mechanical measures: massage by hand, by the static-wave current and sparks or by graduated muscular contraction. These measures must be instituted in accordance with the individual reaction of patients. When the painful nodules are definitely located they must be manipulated or stretched and the patient must be informed that this may involve a great deal of discomfort and at times real pain.

At times very prompt and impressive "cures" can be affected by manipulative procedures in freeing fibrous adhesions and moving joints through a range of motion, which the patient heretofore has not dared to attempt on account of the apprehension of the pain experienced in the acute stage. As a rule, however, long continued local as well as general measures are necessary until the patient is definitely relieved; even then he must be warned to watch out for the slightest evidence of a return of symptoms.

In stubborn form of chronic myositis large doses of galvanism, with the negative pad as the active electrode have proven useful. In recent years very good results have been reported by histamin-iontophoresis, with the technique described in Chapter VIII.

Volkmann's Ischemic Contracture.—Volkmann's ischemic contracture is a typical flexion contracture of the muscles of the fingers, wrist and forearm, described by Volkmann as a result of interference with the circulation in muscle cells from tight splinting with subsequent ischemia and ischemic necrosis. "Once established as an extensive degeneration and atrophy of muscle parenchyma, with fibrosis of the muscle-tendon stroma and secondary involvement of nerve trunks and joints it challenges the most expert attempts at reconstructive surgical treatment" (Ellis[7]).

Promptly recognized early stages of this condition may be benefited by gentle massage, active exercise in a warm whirlpool bath and gentle traction by suitable devices. Even moderately intense heating is dangerous both in early and late stages on account of the existing trophic disturbance and the lack of temperature appreciation by the patient. The author has seen fairly acceptable results in minor degrees of atrophy and fibrosis of forearm muscles in young adults by the systematic application of the whirlpool bath followed by graduated electrical muscular contractions and elastic traction splinting continued patiently over many months.

AFFECTIONS OF TENDONS AND BURSÆ

Tenosynovitis.—The tendon in a tendon sheath has been compared to an umbrella in an umbrella cover. Inflammation of a tendon sheath may follow a local infection, an infectious disease, but most frequently traumatism; the trauma may be one severe blow or multiple minimal strains or sprains; occupational tenosynovitis is due to habitual overuse of a tendon or group of tendons. Tenosynovitis generally affects the sheath more than the tendon itself; its presence is recognized by the patient at first not so much on account of pain which is usually slight, but because of the feeling of weakness when attempting to bring the tendon into use; a palpable and audible creaking (crepitus) may be noted when the tendon is active. The crepitus is due to a deposit of fibrin between the tendon and the walls of the sheath; if, subsequently, effusion of any quantity takes place, a fusiform swelling becomes visible along the tendon and the crepitation ceases. In chronic cases especially when infection occurs, granulation tissue forms within the sheath, firm adhesions develop and interference with free action and marked pain results.

The tendons commonly affected are those of the wrist, thumb, and of the ankle. The extensor muscles are more frequently involved than flexors. Tenosynovitis of the long head of the biceps, as it passes through its sheath in the groove of the humeral head beneath the deltoid muscle, has been described as "golfer's" shoulder. "Trigger finger" is the term used to designate a chronic adhesive inflammation of one of the flexor tendons of the hand. Its usual location is where the tendon passes under the transverse ligament; due to the fibrous organization of a nodule there mechanical difficulty arises on flexion, the involved finger may become locked and on exertion to straighten it out it snaps like a trigger.

Rest is the first consideration in the treatment of acute tenosynovitis. The activities which cause discomfort and pain should be avoided. Luminous heat for periods of one hour twice a day should be instituted at once or else diathermy given by any suitable method for one-half hour daily. In cases which do not respond satisfactorily or which appear as severe cases from the beginning light splinting should be applied in the form of a removable moulded plaster-of-Paris splint or a supporting sling in case of the shoulder. Adhesive plaster strapping for fixation of ankle, fingers or wrist-joint may be used, permitting short-wave diathermy to be applied through the dressing. Massage is usually not well tolerated at the beginning.

In many chronic cases adhesions develop because of thoughtless habit of immobilizing the parts for too long a period. Local heating by paraffin or whirlpool bath or by diathermy, followed by massage, will tend to soften and break up the inflammatory exudate, if not too densely contracted. Smart advises in all cases the early institution of graduated muscular contractions by electrical stimulation.

Bursitis.—Bursal sacs are found between a muscle or its tendon and bone, between two muscles or tendons or between the skin and some harder tissue. They enable movements with a minimum of friction where surfaces move upon another. Being of the same anatomical structure as tendon sheaths and joint cavities, bursæ show the same pathological changes following trauma as infection. These changes have been classified in the following stages:

"1. Acute reactions with effusion or fibrin deposition beginning.

"2. Fibrous adhesions forming and contracting, with associated fascial and sometimes periarticular fibrosis in a contiguous joint.

"3. Muscular atrophy.

"4. Calcium and fat deposition in the bursa or obliterative fibrosis."

Bursal inflammations as a rule gratefully respond to physical measures. Ellis[7] recommends for early local treatment heat, particularly diathermy and absolute rest of the part in a position relaxing pressure upon the affected bursa, also gentle massage up to the threshold of pain for the maintenance of muscle nutrition and for relaxation of spasm. Aspiration is indicated in the first stage as long as the bursa is markedly distended with fluid. In the second stage it is important to prevent fibrous adhesions in or around the bursa, hence while continuing diathermy, gentle manipulations and active stretching exercises are advisable. In the third stage when fibrosis and muscle atrophy have been established Ellis believes that forcible manipulation under gas is necessary, while graduated muscular stimulation initiates muscle retraining. In the last stage diathermy has an almost specific action in hastening resorption of calcium or amorphous fat desposits in the bursa. Wallace[27] stated that bursitis whether of infectious or traumatic origin, readily responds to physical therapy, consisting of early application of external heat and rest during the acute stage; later of diathermy. He recalls no case of bursitis during the past fourteen years that had not responded to such method of treatment.

Superficial Bursæ.—Superficial bursæ are found in many locations under the skin where there is constant or repeated pressure, such as by shoes upon bony parts or deformities of the foot. Pain and swelling over a bunion is usually due to the inflammation of the adventitious bursa located there. Ellis states that inflamed superficial bursæ can be operated upon after which large doses of diathermy, followed by compression bandaging, may result in their obliteration. In simpler forms of inflammation, immobilization of the part and systematic exposure to luminous heat will often satisfactorily control the condition.

Deep Bursæ.—Deeper bursæ are located under muscles (as typified by the subdeltoid bursa), under tendons, fasciæ or in the periarticular structures, and are often connected with a joint. When inflamed they are as a rule not palpable, but produce sharply circumscribed pain in typical locations. Their non-recognition often leads to diagnostic errors. Near the shoulder are the coraco-acromial, subscapular and infraspinatus bursæ; they rarely become inflamed, but if they do, the location of exquisitely tender areas differs from the characteristic local tenderness in subdeltoid bursitis. About the elbow are bursæ under the insertion of the triceps and near the radio-humeral joints. The inflammation of the radio-humeral bursa has been already described as epicondylitis or "tennis elbow" in this chapter.

The *subdeltoid bursa* is one of the largest in the body, about the size of a silver dollar. It is adherent to the inner surface of the deltoid and above to the undersurface of the acromion process and sometimes consists of two portions, subdeltoid and subacromial, which communicate. The bursa encircles almost one-half of the circumference of the humerus.

There is still controversy as to whether subdeltoid bursitis is really the most common cause of shoulder disabilities, as claimed. In the European literature very little is said of subdeltoid bursitis, and the condition usually regarded as bursitis here is described as periarthritis of the shoulder (omarthritis). This term has now begun to be used in the American literature. Other authors attribute the entire symptom complex to subacromial bursitis or calcification of the supraspinatus tendon. The treatment of these conditions will be jointly discussed in the next section.

SHOULDER AFFECTIONS

From the standpoint of physical therapy, the diagnosis and management of shoulder affections is one of the most frequent problems. Among the many reasons for the slow recovery and the painfulness of shoulder lesions are the complex anatomical conditions, the intimate connection of many important structures and the lack of proper vascularization of the shoulder joint. Excessive muscle spasm and radiating pain accompany even minor lesions. Systemic causes often play an important rôle in the etiology and contribute to delayed recovery.

Table 58 shows the various types of painful shoulder affections, with the radiographic findings and points of differential diagnosis. It is evident that a correct diagnosis and the appreciation of the stage and severity of the pathological changes as well of their possible relation to systemic causes are essential as a basis for instituting physical therapy as part of the therapeutic management.

Traumatic lesions of the shoulder are comparatively frequent. The point of the shoulder projects well out from the side of the body, and for this reason it often suffers painful injury; because the head of the humerus moves in a shallow cup formed by an extension of the scapula, the shoulder has less stability and protection than any other large joint. The tendons of the short rotators, the supraspinatus, the infraspinatus, the teres minor and the subscapularis muscles are actually fused with the capsule and play a relatively important part in maintaining the stability of the joint. The supraspinatus tendon forms the floor of the subdeltoid bursa. The intimate connection of so many structures with the relatively unprotected joint leads to frequent multiple involvement in injuries, with subsequent muscle contracture and atrophy, and makes also for difficult diagnostic analysis. Codman[3] and his followers believe that rupture of the supraspinatus tendon is the most frequent traumatic lesion of the shoulder and that the lesion in most cases of subdeltoid bursitis is in fact located in the supraspinatus tendon. Roentgenologically, however, it is possible to differentiate between calcified deposits in the supraspinatus tendon and those in the subdeltoid bursa.

TABLE 58.—PAINFUL CONDITIONS OF THE SHOULDER

Diagnosis	Clinical signs	Roentgenograms	Physical therapy
Contusion, sprain, dislocation, fracture	Vary with injuries	Vary	Indicated
Myositis, tenosynovitis	Tenderness of single muscles and spasm	Negative	Indicated
Acute bursitis	Circumscribed tenderness; few degrees free abduction; spasm	Negative	Indicated
Bursitis with calcification	Same	Positive	Indicated
Brachial neuritis and radiculitis	Sensory disturbance; tenderness of nerve trunks	Negative	Indicated
Acute arthritis (infection)	Swelling; extreme tenderness; all motion restricted by pain; fever	First negative; later vary with degree of destruction	Indicated at times
Chronic arthritis (traumatic, osteo-arthritic, rheumatoid)	Thickening; crepitus; limitation of motion	Characteristic narrowing of joint space; lipping; deposits	Indicated
Neoplasm-gumma	Indefinite	Positive	Contraindicated
Reflex pain	Vary	Negative	Indicated at times

The calcium deposits in the tendinous cuff which forms the capsule of the shoulder joint are recognized as potential sources of shoulder pain, but the origin of the deposits is still obscure. They are often found on roentgen-ray examination of shoulders in which symptoms are entirely absent. Bosworth[1] showed that among 6061 supposedly normal persons of the white collar class, calcium deposits were found about the shoulder in 2.7 per cent. This author reiterated the opinion of other surgeons that a single trauma *per se* does not cause calcium deposition, although it is occasionally associated with the onset of bursitis; that, although fluoroscopically visible calcium deposits may form within as short a period as two months, most deposits require considerably longer for their formation, and finally, that medium and tiny deposits may disappear without symptoms but large deposits result sooner or later in a painful shoulder.

Long-standing bursitis leading to adhesions and considerable limitation of motion has been described by Codman[3] as tendinitis, or "frozen" shoulder, and by other authors as obliterative bursitis. A similar contracture of the short rotators and their ligaments, however, may occur after any trauma or infection as well as after prolonged immobilization of the arm at the side for any cause. Periarthritis or periarticular fibrositis seems to be a more appropriate term for these conditions, although some clinicians apply these terms to all extra-articular disorders of the shoulder.

In minor injuries or other acutely painful conditions, once the proper diagnosis has been established and appropriate surgical care is given, rest is the most important routine therapeutic measure. A sling which supports the elbow and takes the weight of the arm off the painful shoulder is of great help. An ice-bag or ice-cold compress applied to the swollen area immediately after an injury usually relieves pain; it also checks the flow of more blood from torn blood-vessels. After a day or two mild heat radiation should be employed to give comfort and speed up absorption of blood and lymph. In selected cases the use of an ethyl chloride spray followed by active motion may speed up return of motion. As soon as the acute pain is over and there is no complication demanding further rest for the injured shoulder, gentle massage and gradually increased exercise may be started. The intelligent use of these simple measures tends to reduce swelling, to prevent adhesions and to overcome stiffness.

Subdeltoid bursitis is the most frequent cause of painful shoulder and it must be accepted as a definite disease entity, although, for the reasons enumerated, clinically it often cannot be differentiated with certainty from lesions of other closely related shoulder structures. The cause of its inflammation is usually repeated mild trauma associated with calcification; attacks of variable intensity lead to sudden and extreme disablement. However, there is also a primary acute bursitis without calcification which follows a single trauma or an infection. The sudden onset, localized tenderness, limitation of motion due to muscle spasm and the characteristic roentgen picture form the well known clinical picture of subdeltoid bursitis with calcification, acute or chronic.

The generally employed physical treatment of acute subdeltoid bursitis with calcification consists of rest and support in as much abduction as can be secured. Suitably applied heating, especially diathermy, has come to be regarded as the chief stand-by for the relief of pain and muscle spasm. Diathermy is especially effective for the promotion of absorption of the calcareous deposit because of the deep hyperemia it produces. Its introduction some twenty years ago encouraged surgeons to give up the routine advocated by Brickner[2] of operating and cleaning out the bursa. In the acute stage of bursitis the application of radiant heat is often the only measure the patient can tolerate; a small lamp of 150 to 200 watts is used for one-half hour to one hour several times a day. The patient should be kept in bed; the use of sedative drugs may be necessary for a few days to insure rest and sleep. In rare instances any form of heating aggravates the symptoms. In these cases the placing of wet ice packs over the shoulder for the first twenty-four to forty-eight hours with the joint at absolute rest gives the patient much needed relief. The injection of 5 to 10 cc. of 2 per cent procaine hydrochloride solution into the bursal sac frequently aids in ameliorating acute symptoms and histamine ion transfer to the shoulder is often helpful.

After the acute stage careful application of diathermy can begin; in cases in which the onset is less acute it should be started at once. The use of air-spaced plates or of a treatment drum enables one to avoid the slightest pressure on the tender tissues and to keep the amount of heat down to a comfortable minimum. Half-hour treatments are administered twice daily or even oftener. As the tenderness subsides, use of diathermy may be continued by the long wave or by the "contact plate" short-wave method, because it permits exact localization of the diathermic heat and eliminates the scattering of energy and the needless heating of adjacent tissues which occur with condenser pads or an inductance coil. One semi-

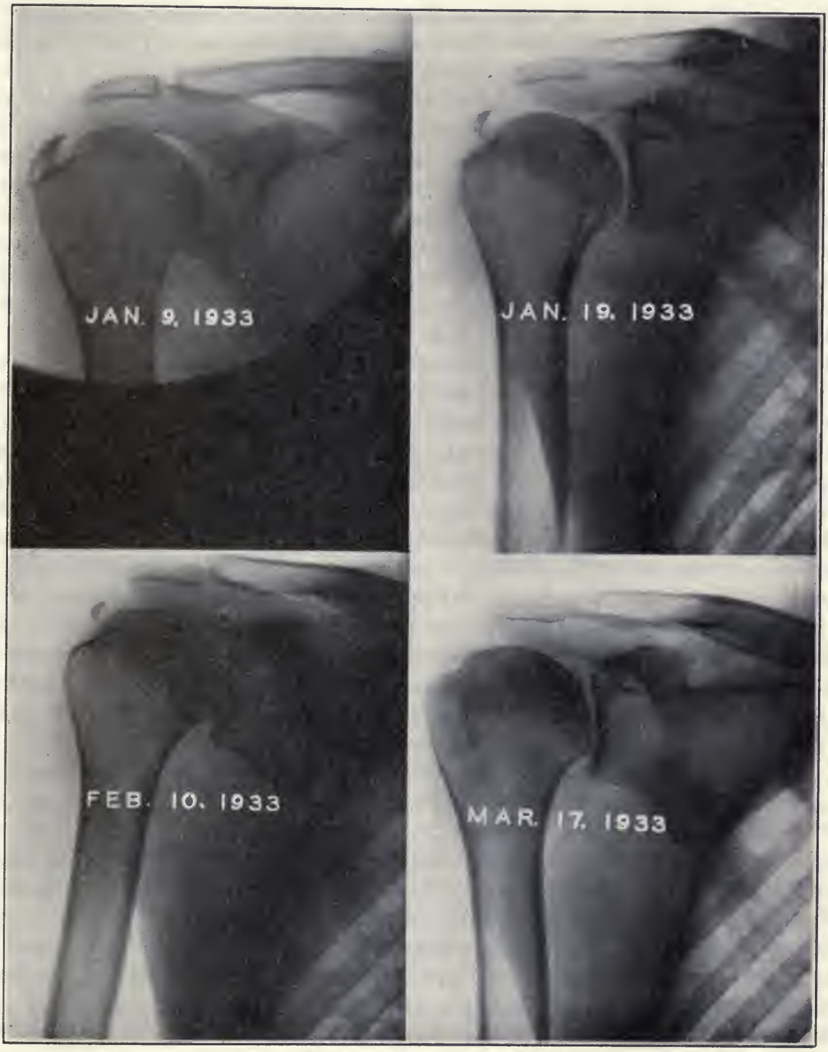

Fig. 304.—Absorption of calcified deposit in subdeltoid bursa during course of diathermy.

cuff electrode is placed above the prominence of the shoulder and the other across the middle of the upper arm. Later, after the bursa has become less tender, the electrodes may be applied to each side of the deltoid muscle in a position slightly tilted forward or in any position in which they include the location of the deposit. Treatments of forty-five minutes to one hour in duration are given first daily, then every other day. The clinical results in my experience and in that of a number of my colleagues appear distinctly superior with this technique. Troedsson[25] in a carefully observed series of cases found the routine anteroposterior technique more effective for the absorption of calcified deposits than the longitudinal technique. Marked neuralgic pain along the arm can often be relieved by a mild application of the monoterminal high-frequency (Oudin) current. A certain amount of active motion should be encouraged from the start to prevent the formation of adhesions and to minimize the secondary contracture of the adductors. Massage or any other form of manipulation as employed by the average operator usually aggravates acute conditions.

In some cases, especially when the patient is a nervous irritable woman, after the subsidence of the local tenderness severe neuralgic pains persist, disturbing the patient's sleep and making her and everybody around her miserable. In these cases in my experience mecholyl ion transfer, applied with the routine technique of asbestos paper saturated with a 0.5 per cent solution and wrapped around the painful area, has frequently given excellent results. The electrode foil or metal plate placed over the saturated paper is connected to the positive pole, while a dispersive electrode placed under the lower part of the back is connected to the negative pole. It is difficult to determine whether the relief obtained is due to the effect on the local circulation or to the mild counterirritation. Suspected foci of infection should be attended to in all cases after the passing of the acute stage.

According to the extent of the symptoms and the size of the calcification, it may take from two to eight weeks of treatment before all clinical symptoms subside and the calcified deposit gradually disappears, as shown by successive roentgenograms. Because of the undoubted length and expense of this course, irrigation of the bursa and "needling" the deposit itself by multiple punctures have been advocated for acute cases. It is claimed that through the puncture holes the calcareous material on the floor of the bursa is liberated into the bursa, relieving the tension, while the increased vascularization following the trauma promotes absorption. The author has had no first hand experience with this procedure, and so far no comparative statistical evaluation has been published.

In chronic bursitis, in which chronic periarthritis brings about painful adhesions and stiffness, a systematic course of diathermy is logical as the first line of attack, but it must be combined with systematic exercises, such as wall climbing or circumduction. This may be followed by mild stretching. (Figs. 274 to 278.) Only if such a regimen proves ineffectual should manipulation under anesthesia or operative excision of the bursa be considered. Bosworth recommended that in all cases of calcification large deposits be excised, regardless of symptoms, to forestall the development of an acute attack of bursitis. He confessed, however, that no patient had yet been willing to have this done. Excision of a bursa is a procedure which means hospitalization, with its attendant expense, plus the time required for healing of the operative wound and the resultant scar; manipulation under anesthesia must be also followed by a period of suspension and traction plus prolonged physical therapy. Hence, the routine of systematic conservative therapy seems generally preferable.

The results of roentgen therapy in the treatment of subdeltoid bursitis have been compared with those of short-wave diathermy by Solomon and Morton.[23] Both methods appeared capable of securing relief in a large percentage of cases in a relatively short time, and the results were identical. The diathermy technique employed by these authors consisted of an inductance coil applied for a maximum of twenty minutes three times a week. Perhaps with the more efficient technique described previously the results of diathermy would have been still better. So far as the saving of time is concerned, no advantage has been claimed for either procedure.

Rupture of the supraspinatus tendon as a cause of an acutely painful shoulder may as a rule be recognized by the rather violent trauma preceding it and the immediate inability to abduct the arm. It is most frequent in laborers. The question of suturing must be decided by the surgeon. In the after-treatment, physical therapy is applied on the same principles as in bursitis. Many patients with undoubted partial rupture fully recover with conservative treatment.

Calcification of the supraspinatus tendon may cause pain, spasm and limitation of motion similar to those in acute bursitis. Suitable roentgenograms taken in several planes will locate the deposits. The same physical therapy routine is applicable as in calcified bursitis. Dick and Hunt[4] corroborated the value of diathermy in this condition; in addition, they recommended large doses of ammonium chloride for producing mild acidosis, which tends to cause absorption of deposits.

Arthritic involvement of the shoulder is comparatively infrequent but must always receive diagnostic consideration. Synovitis or acute arthritis occurs after trauma or an acute infection and responds to the measures recommended for acutely painful conditions. Pyogenic infection is a surgical problem. Chronic arthritis, osteo-arthritic or atrophic, is usually part of a general arthritic condition in which more than one joint is involved. Traumatic arthritis may also occur in some instances. Physical treatment, local as well as systemic, forms an essential part of the treatment. Tuberculosis of the joint is insidious in onset and can be differentiated only by the characteristic roentgen findings. Its treatment requires a general regimen of rest and heliotherapy. Gonorrheal arthritis of the shoulder is rare. In all conditions of joint involvement, studies of an infective aspect are essential to appropriate treatment.

Non-articular "rheumatism" about the shoulder includes bursitis and myositis, acute or chronic, in one or more muscles, following exposure or infection. Various forms of nerve lesions also belong to this classification; these are neuralgias, as already described, and typical neuritis and radiculitis. Root pressure from arthritic deposits in the cervical and upper dorsal part of the spine appears to be a more frequent cause of such shoulder pain than focal infection (the rôle of which has been much overemphasized in years past). The author[13] showed some years ago in a series of 151 cases of involvement of the shoulder that focal infection played a minor rôle in the causation. More attention has been given recently to the cervicobrachial syndrome (Naffziger and Grant,[18] Hansson[11]) as a cause of pain and other symptoms in the shoulder and upper part of the arm. Physical therapeutic measures in the form of heat, suitable exercise and mild counterirritation should serve as useful adjuncts in the management of most of these conditions. The success or failure of certain physical measures may offer at times valuable differential diagnostic evidence, corroborating for instance the diagnosis of simple myositis or fibrositis.

Finally, mention must be made of well known instances of shoulder pain due to a reflex from a cardiac or gall-bladder condition, and there also occur instances of more obscure pain due to a new growth or gumma somewhere in or near the structures of the shoulder. A complete diagnostic check-up and continued observation are the only safe means of recognizing and appropriately managing these rarer conditions. The accompanying table shows the classification of all painful shoulder conditions and some of the diagnostic aspects.

MISCELLANEOUS SURGICAL CONDITIONS

Adenitis.—Primary adenitis in both children and adults often shows favorable response to light therapy, especially adenitis of tuberculous nature. In hard enlarged glands, a combination of local and general ultraviolet irradiation, preceded by local application of luminous heat, is advisable. The latter is applied for one-half hour to the glands, followed by general ultraviolet in increasing dosage, three times weekly; finally local ultraviolet is applied in third-degree erythema dosage, repeated when the reaction subsides. Irradiation from an efficient carbon arc source may be often preferable. This course of treatment usually requires several weeks before the glands are reduced in size. At times additional roentgenray radiation may be advisable.

If the glands have broken down, they must be drained and general ultraviolet irradiation, possibly combined with local radiation through a quartz applicator, be continued. Ulcerated and deep-seated glands with sinuses call for intense and protracted radiation and skilful surgical treatment.

Burns.—The explosive and incendiary agents of modern warfare are producing a very large proportion of burns among casualties. The primary treatment in all cases of extensive burns (10 per cent or more of the body surface) is prevention or limitation of shock by injection of morphine and the administration of fluids—whole blood, blood plasma or saline solution. The previous teaching of applying external heat to severely shocked patients is now questioned on the basis that cutaneous vasodilatation causes peripheral accumulation of blood and thus contributes to circulatory collapse.

There is no universal agreement as to the best method of immediate local treatment except that the application of some form of coagulating agent appears to be the most practical type of treatment. The National Research Council recommends for immediate application to all parts of the body other than the face, hands and genitalia, a water-soluble jelly containing 10 per cent tannic acid and 5 per cent sulfadiazine, or, in the absence of such a preparation, tannic acid ointment. A sterile gauze covering should be used over the injured parts. In the later stages of treatment a heat tent or, in cases of extensive burns, a thermostatically controlled saline bath may be employed.

After all sloughs have disappeared and the wound is cleanly granulating, ultraviolet irradiation may be employed to promote regeneration or to prepare the field for skin grafting. One has to be careful to apply minimal dosage only because the newly formed epithelium is very sensitive to the short ultraviolet rays. The burn is cleansed and covered with a film of thin paraffine; ultraviolet irradiation from a mercury vapor lamp is given with a first degree erythema dose (two minutes at 30 inches) and repeated daily. The film of paraffine acts as a filter to keep off the short ultraviolet rays (below 2400 Angstroms) and serves as an innocuous dressing between treatments. If the lesion is markedly infected, a 50 per cent, heavier dose is given in the first treatment and the milder dosage continued.

It is important that in the stage of healing the development of contractures be minimized by active and passive motion and early massage and that this treatment be kept up for a sufficiently long period.

Small burns can be treated with the water-cooled ultraviolet or thin window lamp in first degree erythema doses, preferably through a thin paraffine covering. These lesions can be kept dressed with plain gauze pads soaked in paraffine and the irradiation repeated daily.

Scars.—Light superficial scars may be subjected to the softening effect of the negative pole of the galvanic current, which makes them more amenable to subsequent mechanical stretching by massage. The procedure is known as chlorine ion transfer and its general principles have been described in Chapter VIII. An active electrode corresponding in size to the scar is made of twelve to fifteen layers of gauze, is soaked with 2 per cent common salt solution; on it is placed a metal electrode of somewhat smaller size and connected to the negative pole. The large dispersive pad may be laid over any convenient part and is connected to the positive pole. The current strength depends on the size of the active electrode; it may amount anywhere from 2 to 20 milliamperes. Beneath the active electrode sodium hydroxide is formed, and being mildly caustic its prolonged action softens light scar tissue. The current strength must be always within comfortable toleration of the patient. On account of the frequency of sensory disturbance over scars, it is necessary to proceed most carefully. Excessive current density over scars may cause burns leading to slow healing ulcers; if during treatment the patient cannot exactly state whether there is any burning sensation or not, one should turn off the current and inspect the site of the active electrode. Marked reddening in a circumscribed area is a sign of excessive current density and indicates the danger of a burn. The average treatment should last from one-half to one hour.

FOOT CONDITIONS*

The treatment of foot disorders offers a vast field for the application of physical therapy. To neglect physical measures in this work is to overlook an excellent means of bringing relief in many conditions.

The common *weak foot*, with its tendency to pronate, requires orthopedic care for its correction. Proper exercise designed to relax the peroneal muscles is of great assistance, and can be kept simple and easy. Gentle low-frequency sinusoidal stimulation is also helpful, and can be easily administered with the patient seated and each foot placed on a separate pad on the floor.

Many foot ailments, as well as complaints of remote distress, can be traced to the syndrome of *tight posterior muscle groups* of the legs. Foot examination should always include a test of these muscles. If found

* This section was kindly contributed by Jerome Weiss, M.D., Attending Physical Therapist, Hospital for Joint Diseases, New York, and Assistant Professor of Orthopedics, Long Island Medical College Hospital, Brooklyn.

abnormally tight, suitable exercise must be taught the patient to secure relaxation of the muscles.

The treatment of *calcaneal* and other *spurs* is of course surgical. But frequently operation is contraindicated or is undesirable for some reason, and relief of symptoms must be sought otherwise. Here physical therapy is of the greatest value. Diathermy carefully applied will usually afford complete relief of symptoms, although it will in no way change the appearance of the spurs on roentgen-ray examination. Reduction of inflammation and relief of the bursitis is accomplished, with resultant disappearance of pain and disability. This explanation is logical when we consider the patient who complains of a painful heel of two weeks' duration, and on roentgen-ray examination shows a calcaneal spur which was certainly many months in developing. Occasionally no pain is felt until a spur is fractured.

For treatment of the calcaneal spur, either plantar or posterior, long-wave diathermy may be applied by the transverse or by the longitudinal method with equal facility. For the posterior spur it is better not to attempt application of the diathermy plate directly over the site, as it is difficult to obtain good contact. Short-wave diathermy may be used in the treatment of spurs, but if possible contact electrodes with an ammeter in series should be used. Ion transfer with histamine or mecholyl has also been used successfully in the treatment of painful spurs.

Hallux valgus, or *bunion,* is another condition which calls for orthopedic correction, either by operation or splinting. Proper shoes must also be prescribed or all attempts at relief will fail. In this painful condition diathermy properly applied will frequently give complete relief of symptoms, though here again the roentgen-ray findings will remain unchanged. However, unlike the case of spurs which usually shows little or no disturbance externally, the clinical picture of the hallux valgus case is decidedly improved following successful therapy. Inflammation disappears, movement of the joint is improved, and masses which were apparently bony soften and flatten out.

Diathermy may easily be applied to a bunion by means of small plates above and below the joint, firmly fastened to assure good contact. Attempts to cup a plate over the bunion should be avoided, as this method is painful and usually is less satisfactory. An excellent method of applying the diathermy current in a case of hallux valgus, though one which is a little more troublesome, is by use of a rubber glove as a shield for the foot and a dish of saline for contact. The thumb is cut off an old surgical rubber glove, which is then slipped over the foot so that the great toe protrudes through the hole left by the loss of the thumb. The glove is drawn well up on the foot so that the metatarsus is covered. A metal cuff is applied above the ankle, and the foot is placed in a dish of saline so that the toes are immersed. Care must be taken that the upper edge of the rubber glove is above the surface to avoid short circuit of the current. A strip of metal clipped to the side of the dish contacts the saline and completes the circuit.

In using this method we are assured that the diathermy current is directed through the inflamed joint and bursæ, with no danger of slipping plates. A small current loss will occur by displacement through the rubber, but this will remain very low because of the slight difference of potential. Short-wave diathermy may also be used in the treatment of hallux valgus, but here again the use of contact electrodes and the series ammeter are preferred. Iontophoresis using histamine or mecholyl also has given very favorable results in the treatment of this distressing condition.

Superficial infections of the foot are particularly amenable to treatment with ultraviolet light, more so to the shorter wave-lengths found in the cold quartz lamps. Possibly this is due to the fact that the infecting organisms had found their best environment in the darkness and diminished air supply of the leather shoe. The use of cold quartz therapy should always be an adjunct to the treatment of infections of the foot and their causative pathology, such as ingrowing toe nail.

Surgical diathermy finds excellent application in the treatment of benign but disabling *neoplasms* of the foot. Plantar helomata and verrucæ respond well to both monopolar and bipolar treatment. Care must be taken to avoid development of painful scars, though the danger of this mishap is less when using the diathermy methods than it is following surgical excision. The galvanic current has also been used in the treatment of plantar warts, but this method now has few followers.

The use of copper iontophoresis in the treatment of fungus infections, as described elsewhere, constitutes a valuable aid to the control of this obstinate condition.

In the treatment of *circulatory disorders* of the feet passive vascular exercise has proved to be of the greatest assistance. It has materially improved the prognosis in cases of frostbite, arteriosclerosis and Buerger's disease. Apparatus for administering passive vascular exercise has been greatly improved to supplement the original simple exercise introduced by Buerger. The thermostatically controlled baker is an example of the modern efficient aids for restoring circulation to the feet in vascular disorders. (See also Chapter XXIV.)

Painful *bursitis* may occur at many points of the foot, either in conjunction with a spur or hallux valgus, or independently of any such condition. Here we have the choice of two excellent methods of treatment, diathermy and iontophoresis. Care must be taken that the affected bursa receives the full benefit of the application, without excessive by-pass through the surrounding tissues.

Arthritis involving the numerous joints of the foot is of particular interest because of its obstinacy and disabling nature. Physical therapy is a particularly valuable adjunct to the treatment of arthritis of the foot. Treatment of the arthritis which usually complicates a hallux valgus has already been described. At the correct stages diathermy and iontophoresis find excellent application for arthritic involvement. Gonorrheal arthritis is an extremely painful complication which responds in a most gratifying manner to the use of diathermy. This may be applied even in the acute stage, but great care must be observed in the application of the electrodes because of the severe pain on movement. Here the use of short-wave diathermy with condenser electrodes will eliminate much manipulation otherwise unavoidable. In many types of arthritis involving the foot the use of histamine or mecholyl by iontophoresis either alone or alternated with diathermy treatment should be considered.

In *tuberculosis* of any structure of the foot, as elsewhere in the body, the use of ultraviolet light, both local and general, is indicated.

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CHAPTER XXX

GYNECOLOGICAL CONDITIONS

General Considerations. General Rules of Technique. Electrodes. Pelvic Heating by Diathermy. Pelvic Heating by Non-electrical Methods. Inflammatory Conditions. Gonorrheal Cervicitis and Urethritis. Pelvic Inflammations. Chronic Endocervicitis. Non-inflammatory Conditions. Infantile Uterus With Stenosis of Cervix. Amenorrhea. Sterility. Dysmenorrhea. Menopausal Syndromes. Minor Surface Growths.

General Considerations.—Physical measures serve as important adjuncts in the treatment of conditions peculiar to women in the hands of the physician who can make a correct gynecological diagnosis and who has training and experience in using these measures.

Local infections of the female genital tract form the largest group of conditions amenable to treatment by physical measures. In gonorrheal and postpartum infections, endocervicitis and pelvic inflammations, electrothermal and electrochemical measures serve to relieve pain, to overcome the infection and to speed up the resorption of the products of inflammation. External heat is employed in the form of hot baths, hot irrigations, infrared radiation, "baking" by dry heat and heat lamps. Long- and short-wave diathermy serve as methods of penetrating heat in controllable intensity and location. Artificial fever treatment makes possible the efficient and rapid combating of all forms of gonorrheal infections resistant to chemotherapy.

The galvanic current in the form of copper and zinc ionization has been used for many years for its germicidal and mild coagulative effects upon the more superficial forms of chronic infections. Recently good results with pelvic iontophoresis by vasodilating drugs have been reported. Negative galvanism serves to soften and gradually dilate the cervix in congenital and acquired stenosis. Low-tension wave currents are useful in developing the musculature of an infantile uterus and in toning-up and strengthening relaxed pelvic muscles after childbirth and after plastic operations.

There is a large field for electrosurgical application in gynecological conditions. The ready accessibility of the female genital tract lends itself to the comparatively easy yet thorough destruction of surface growths and to the destruction of diseased epithelial lining in the cervix by electrosurgical methods. The choice of method is the task of the expert gynecologist and operator.

The patient as a whole has to be considered in gynecology even more than in other departments of medicine. Here again physical measures in the form of ultraviolet irradiation, light cabinet baths, massage and corrective exercise offer valuable help for amelioration of a temporary anemia, a functional nervous disorder, an asthenic constitution or postural imbalance.

General Rules of Technique.—Electrical applications in gynecology must be carried out under the same rules of asepsis as any other gynecological examination or instrumentation. The hands of the operator must be scrubbed and preferably covered with rubber gloves. Specula and some of the metal and glass instruments are boiled. Electrodes which cannot be subjected to boiling can be sterilized over a flame. After use each instrument should be cleansed immediately of mucus and pus by wiping and then held under running cold water. Mucus is soluble in water but if heat or bichloride is used the mucus coagulates and will stick to the instrument. Next, the instrument is thoroughly washed with soap and hot water and then boiled if possible or put in a compound solution of cresol for ten to fifteen minutes. Before the instrument is used again it must be well dried with clean gauze.

The vaginal walls, cervical canal and urethral meatus should be swabbed free from secretions before treatment. It is possible and preferable to insert the cervical electrode without using traction forceps on the cervix. As both the cervix and the vagina are relatively insensitive to heat or to chemical action, with every intra-vaginal application carried to excess, there is danger of a sloughing burn without any warning complaint on the part of the patient. It is advisable, therefore, to keep a record of the dosage administered at each treatment and to make an inspection through a speculum prior to each application.

FIG. 305.—Vaginal electrode with thermometer. (Courtesy of the General Electric Corp.)

Electrodes.—Transpelvic (abdomino-sacral) forms of treatment are applied with electrodes placed over the abdomen and under the sacrum. Other forms of treatment call for the use of an active electrode within the genitalia or in the rectum and that of a dispersive electrode on the outside. (Figs. 306–308.)

The active electrodes for gynecological applications are usually made of metal of a shape and size to conform with the urethra, cervix or vagina and are mounted on an insulated handle. Galvanic and low-frequency currents exert ionizing effects around a metal electrode no matter to which pole it is connected. While it is true that metallic ions are only diffused when the electrode is connected to the positive pole, nevertheless the nascent sodium ions around the negative pole attack the metallic coating of the electrode also and take away its smooth and bright appearance. Carbon-tip intravaginal electrodes have been recommended to overcome this. For the routine reamalgamation of copper or metal electrodes with mercury, one can use the solution of Derow, consisting of $\frac{1}{4}$ pure nitric acid and $\frac{3}{4}$ of water, to which a few drops of metallic mercury are added. The electrode is dipped in this solution before each treatment and becomes sterile and its surface smooth.

For non-ionizing currents—diathermy and the static current—the same electrodes or simple nickel-plated electrodes may be employed. Any metal sound of suitable size, insulated over the portion which is in contact with parts not to be heated can be used for applying diathermy to the urethra and cervix. Specially constructed electrodes with arrangement for thermometry are also available. The principal part of these is a thin-walled metal tube mounted in an insulating hard rubber tube; the first tube contains the thermometer; if its tip is inserted into the urethra or cervix the thermometer shows an approximately correct reading of the temperature of the parts immediately around the metal tip.

The *thermophore* of Corbus and O'Conor[5] is the best known universal diathermy electrode for thermometric purposes. It is available in three sizes, fitting the cervix of either a nullipara or a multipara and the urethra, respectively.

The *pelvic diathermy electrode* of Zener consists of a hard rubber vaginal speculum of the Ferguson type, fitted with four similarly curved blades. The two outer vaginal blades may be expanded laterally so as to conform to the vaginal fornix and cul-de-sac; the two cervical contracting blades fit against the cervix. It is claimed that this electrode enables the passage of a larger current directly through the body of the uterus and the adnexal regions and that a thermometer passed through it in the cervical canal showed that cervical temperatures of 110° F. may be maintained if desired.

The same electrodes can be used as active electrodes for both long-wave and short-wave diathermy; glass insulated electrodes recommended abroad for short-wave diathermy have not been found satisfactory.

As *dispersive* electrodes, for galvanic and other low-tension and low-frequency treatments, moist pad electrodes of suitable size are used. For diathermy, plain metal electrodes of similar size or a belt electrode encircling the pelvis may be used. For short-wave diathermy large size condenser pads with suitable spacing serve as dispersive electrodes.

A belt electrode has been recommended as a dispersive electrode in all intravaginal, cervical, urethral or rectal treatments, with the reasoning that it would insure an even distribution of current all around the active electrode. An electrical current has always the tendency to complete its circuit along the shortest path; as there is bound to be a difference in the distance either anteriorly or posteriorly, from the active electrode to the belt, the main part of the current will travel, as a rule, along whichever path is the shortest one. In copper ionization of the cervix, when a single dispersive pad is applied either over the abdomen or under the back, an even ring of green discoloration will occur in either case all around the cervix, proving that in the immediate vicinity of the active electrode the current distribution is fairly equal. It is usually sufficient, therefore, to use a metal plate, 3 by 5 inches or larger, as a dispersive electrode and place it either just above the symphysis or under the sacrum; there is no objection to placing an electrode over each location and connecting both to one terminal of the apparatus.

Pelvic Heating by Diathermy.—One can treat all pelvic organs *en masse* by the abdomino-sacral or transpelvic technique; each organ can be treated individually, using special electrodes in the interior of the pelvis in close proximity to the part to be treated. The latter technique produces localized heat of a definitely known degree, and it is, therefore, more efficient and more generally employed.

Transpelvic (Abdomino-sacral) Diathermy.—This technique is indicated in inflammations of the entire pelvic contents or whenever it is impracticable to apply the more efficient vaginal or rectal method. The patient lies on her back; for long-wave diathermy or short-wave by the contact plate method the sacrum rests on a plate, 4 inches wide and 5 inches long. If there is a hollow under the lumbar spine a flat sandbag or folded towel will be needed to secure firm contact under the sacral electrode. The other electrode about 3 by 4 inches in size is placed just above the symphysis and is secured in place by a small sandbag. A larger electrode is used in the back because most patients are quite sensitive to heat there; the reason for this is most likely the limited amount of collateral circulation over the bony sacrum to take away excess heat and the additional anemia caused by the weight of the body pressing upon the plate. Hence it is safer to produce less local heat under the posterior electrode. About 1000 to 1200 milliamperes can be comfortably applied by this method and the treatment is to be kept up for twenty-five to thirty minutes.

Short-wave diathermy to the pelvic contents can be applied by the electric field method with two suitably spaced condenser plates placed similarly as in the long-wave method just described; the other more generally used method is the electromagnetic field method, with a pancake coil over the lower abdomen, with the interposition of suitable spacing—several thicknesses of bath toweling—according to the output of the apparatus.

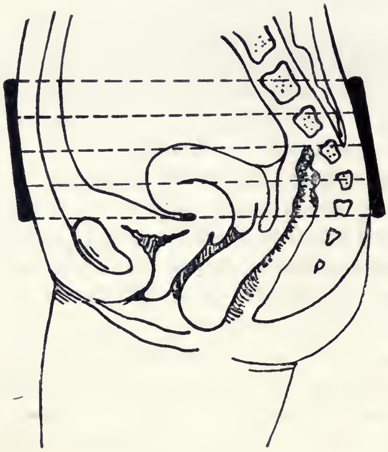

Fig. 306

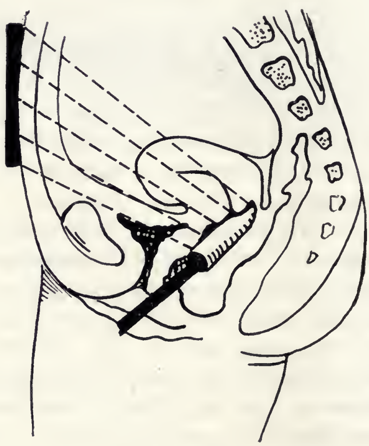

Fig. 307

Fig. 306.—Transpelvic (abdomino-sacral) diathermy. Actually the lines of current distribution do not form a straight line.

Fig. 307.—Abdomino-vaginal diathermy.

Vaginal (*Abdomino-vaginal or Intravaginal*) *Diathermy.*—A vaginal electrode of suitable size and shape, usually cylindrical, is placed directly against the cervix and cul-de-sac, and a metal belt electrode is placed around the hips, or one plate electrode is applied above the symphysis and connected to the other terminal. (Fig. 307.) The vaginal electrode being smaller, serves as the active electrode and, through its close contact with the internal genitalia enables the production of intense local heating. The electrode may be all metal or it may consist of a blunt metal cylinder, usually with suitable depression for the cervix, mounted on a hard rubber shaft. A terminal on the latter serves for the attachment of the cord.

The vaginal electrode may be safely held in position by a few sandbags of suitable size, between the flexed thighs of the patient.

The employment of a vaginal electrode enables the fairly even distribution of heat in all directions around the cervix. About 1000 to 1500 milliamperes can be applied, and usually all that the patient feels is mild heat under the belt electrode. If the contact is poor there may be some faradic sensation. The cervix itself is not sensitive to heat and the mucous membrane of the vagina offers very little resistance, hence the necessity to watch the milliammeter for any sudden rise, which would indicate some interference with the circulation and danger of local electrocoagulation. The maximum heat is developed in the parts next to the metal end.

The intravaginal technique is principally used for treating diseased tubes, ovaries and parametria, and Cumberbatch suggested the term of general pelvic diathermy for it. The vaginal electrode with a thermometer allows a fairly accurate estimate of the heat produced around the electrode.

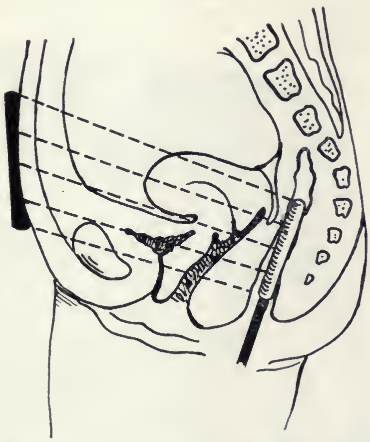

FIG. 308.—Abdomino-rectal diathermy.

Rectal or Abdomino-rectal Diathermy.—A cylindrical electrode on an insulated stem is inserted into the rectum as the active electrode, while a plate, 4 by 5 inches, placed above the symphysis serves as a dispersive electrode. The patient resting on her back, the rectal electrode, well lubricated, is inserted by a gentle turning motion and held in position by a sandbag. The dispersive electrode is held by a sandbag. About 500 to 1000 milliamperes can be comfortably tolerated, depending upon the size of the rectal electrode and on the sensitivity of the patient. This technique may be used as an alternate method for applying diathermy to the body of the uterus and to the adnexa and pelvic supporting tissues. It is less effective, however, than the vaginal method.

Pelvic Heating by Non-electrical Methods.—The *hot douche* is a time-honored, inexpensive method conveying heat to the pelvic organs. In order to be effective it must be administered in the lying-down position, from a douche bag hung at a height about 2 feet above the pelvis, at a slow rate of flow, for at least thirty to forty-five minutes and a water temperature from 98° to 110°, depending on the pathology and the patient's sensitiveness. It may be best taken in the bathtub, if the bathroom is not too cold or the patient is covered with blankets in the tub—or on the edge of the bed—the patient lying relaxed on a douche pan or on a piece of oilcloth the lower end of which is rolled into a conical spout, that leads into a slop pail. The douche is preferably taken at bedtime or when complete rest for the relaxed organs can be assured. It can be employed as a home treatment for pelvic pain and inflammation; addition of sodium bicarbonate will help to dissolve mucus and allay itching, as well as to neutralize acidity. The chief problem in effectively using the douche is that patients learn to control the flow of water, relax properly and take the douches long enough and regularly—daily or three times a week as indicated.

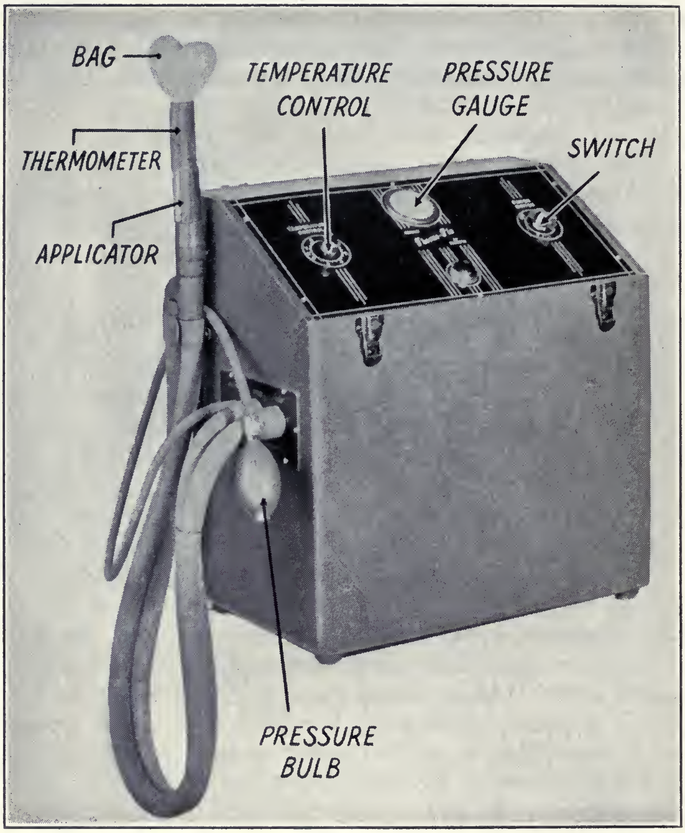

Fig. 309.—Device for superheated air treatment of pelvic contents. (Newman.)

The *Elliot treatment regulator*, described in Chapter XX, is in fact a dry douche, given for forty-five to sixty minutes, at a temperature gradually increased to around 128° F.; this raises the urethral temperature to 104° and the rectal temperature to 106° F. in the average. It is applicable in all forms of inflammations, but it requires careful supervision because of the possibility of burns and scaldings and is therefore chiefly an institutional procedure.

Superheated air for intravaginal treatment can be applied by the apparatus shown in Figure 309. The air is heated by a small electric unit and circulated by a motor-driven fan in a specially shaped thin-walled rubber bag, which is inserted into the vagina in a collapsed state and then inflated with air by a rubber bulb so as to distend the vagina. A pressure gauge indicates the pressure which is about 1 to 1½ pounds. Treatment is administered at a temperature up to 130° F. This arrangement allows conductive heating at a uniform pressure without the discomfort of a heavy water-filled bag and with increased security from scalding by hot water in case of occasional bursting of the bag. The indications for applications are also the various pelvic inflammatory conditions. (Newman.[13])

Radiant heating from a tubular light bulb housed within a sturdy glass speculum placed in the vagina was proposed by Bengston[1] recently. He claims that this device enables him to maintain safely a tissue temperature just under 114° for ten to twenty hours; a voltage regulator indicates milliamperes of electric energy and the temperature of the vaginal mucous membrane is also shown.

Pelvic Iontophoresis.—The use of mecholyl ion transfer in pelvic inflammatory conditions, specifically in massive cellulitic infections of recent origin which failed to yield to ordinary treatment, was recommended by Gordon and Rosenthal.[9] The technique consists of wrapping about the end of a vaginal electrode a suitable piece of gauze saturated with a 0.5 to 1 per cent solution of mecholyl chloride; this is applied through a speculum against the vaginal vault, after it has been wiped dry. The electrode is connected to the positive pole of a galvanic generator, while a 6 to 8 inch size moist dispersive pad is placed over the abdomen and connected to the negative pole. Treatment is administered for twenty minutes with a current strength gradually increased to 15 to 20 milliamperes. Some of the effects of this application may be due to the galvanic current itself which in its early days was extensively used with a similar technique. Craig and Kraff[6] reported good results with pelvic mecholyl ion transfer in acute pelvic inflammations of tubal origin.

INFLAMMATORY CONDITIONS

Gonorrheal Cervicitis and Urethritis.—In acute gonorrheal infections chemotherapy is the generally accepted first line of attack at present. In resistant acute cases as well as in subacute and chronic cases intense local heating by diathermy or general heating by hyperthermy are still the standbys of physical treatment, because of the thermal vulnerability of the gonococcus.

The classic method of Cumberbatch[7] in local diathermic treatment of cervicitis and urethritis is based on long-wave diathermy. Cumberbatch found that the cervix uteri can be heated to 120° F. and the urethra to 105° F. without damage, and that a maintenance of this temperature for ten minutes, repeated if necessary, was sufficient to eliminate many cases of gonorrheal infection. The technique consists of applying a belt electrode as a dispersive electrode and a special urethral electrode as the active electrode. The current is turned on and gradually increased until the patient has the sensation of heat in the urethra; it is then slowly increased further until the sensation of heat changes to one of pain and then slightly decreased until all feeling of pain disappears. In working out this technique with the aid of thermometers it was found that pain was usually felt between 114° and 115° F. The strength of the current at this point—the degree of heat that the patient can stand without pain— is maintained for ten minutes and the reading of the milliamperemeter is noted, as it forms the guide to the strength of the current to be applied in the treatment of the cervix which is insensitive to heat. After the urethral treatment the cervix is exposed by a vaginal speculum and the cervical electrode is introduced into the cervical canal, to a distance of ¾ inch. The current is turned on gradually and kept at one-half of the milliamperage which was used in the urethra. This amount will produce the same temperature in the tissues of the cervix because the diameter of the electrodes is the same but the contact surface of the urethral electrode is larger; therefore, less current is needed to produce the same current density around the cervical electrode. This current strength is maintained also for ten minutes.

Cumberbatch and Robinson found that with the technique outlined and treatment applied from three to eight times at intervals of three to seven days or about twice a week, it is usually possible to eliminate the infection, as shown by laboratory tests. Corbus and O'Conor[5] developed a technique with the "thermophore" introduced into the cervix and with a belt electrode applied around the lower abdomen and pelvis. The current is turned on gradually and increased until the thermometer registers 116° to 117° F. and continued for thirty to seventy minutes at this strength. According to these authors, this treatment repeated every eight to ten days resulted in the elimination of gonorrheal infection in practically all cases where the infection was confined to the cervix. The thick purulent discharge took on a thin watery character and the accompanying cervical erosions healed over. Treatment is continued until five successive smears, one of which is taken forty-eight hours after cessation of menstruation, are negative.

Combined systemic heating by fever therapy and pelvic heating by long-wave diathermy (Bierman and Horowitz[2]) is applicable in chemoresistant and chemosensitive cases. First the systemic temperature is elevated (usually by a heating cabinet) and held for twelve hours between 105.5° and 106.5° F. During this period, for seven to eight hours, pelvic temperatures of 109° to 110° F. are maintained by means of high-frequency currents. A vaginal electrode equipped with a thermometer is used as an active electrode and four cuff electrodes applied on the lower extremities serve as dispersive electrodes. Following six or seven hours of this local heating, one or two hours of pelvic heating by short-wave diathermy, using the same vaginal electrode is administered. A more rapid destruction of gonococci by this method is claimed. This is a drastic treatment, to be administered only in hospitals and with a personnel qualified by special training and experience.

Pelvic Inflammations.—Pelvic inflammations are caused by infection by the gonococcus or pyogenic bacteria. The gonorrheal infection is practically a self-limited pelvic disease, progressing on the surface and causing typical pathological changes in the pelvic organs, such as inflammation of the adnexa, pelvic peritonitis, parametritis and pelvic cellulitis. Pyogenic bacteria, due to septic abortion, septic childbirth, instrumentations, etc., cause more severe inflammation, invasion of bacteria through the blood and lymph circulation into the pelvic tissues, and the pathological changes are more severe than the gonorrheal inflammation. Thermal measures are practically specific in their action on most cases of pelvic inflammation.

Diathermy is a most satisfactory agent for treatment of these conditions and seems to act best when the inflammation is interstitial as in chronic parametritis. Cherry[4] reported that diathermy relieves pain, diminishes the pelvic masses and aids in restoration. Used as a preoperative therapeutic measure, it will eliminate many of the technical difficulties in the removal of large pelvic masses and thereby contributes to a smoother convalescence. Incidentally the percentage of postoperative wound infection is lessened. Sheffey and Schmidt[15] emphasized that less technical difficulty was noted in the operative cases preceded by diathermy, as evidenced by decreased density of adhesions and their more ready separation. Either short-wave or long-wave diathermy can be employed; the latter method still seems the more preferable because its technique is simpler and it enables the use of a milliammeter. The various techniques have been discussed in the preceding pages. From 1000 to 1500 milliamperes of current should be applied, in stout women as much as 2500 to 3000 milliamperes. The length of treatments should be from one-half to one hour, repeated daily or every other day according to conditions.

As to the relative value of the two forms of diathermy in inflammatory conditions clinical observers have reported that the advantage of short-wave application is the applicability and efficiency in acute cases. Long-wave diathermy seemed to be preferable for intense localized heating in chronic cases. As to the claim of more intense depth effect by short waves, Scholtz[14] found with long-wave diathermy electrodes of sufficiently large size deep heating effects equal to those produced by powerful short-wave apparatus. The contention that short-wave diathermy is specifically beneficial in acute cases may be partly explained by the fact that in such cases it is usually administered in very low dosage and mild heating is usually well tolerated even in acute inflammations. A recent report by Upton and Benson[17] in 100 cases of gonorrhea, postabortal infection and postoperative complication states that best results were obtained with long-wave diathermy for which a vaginal electrode was used and when a moderately high temperature was sustained.

The contraindications to diathermy as well as other thermal application to the pelvis are acute infections, bleeding, pregnancy, localized pus and loss of skin sensitivity.

Each of the other non-diathermic thermal applications have their advocates; their range of applicability and contraindications are similar to those of diathermy. For office use by physicians diathermy appears to be the simplest and most efficient method.

Chronic Endocervicitis.—Cervicitis is produced by the gonococcus or by non-specific pyogenic organisms which have gained a hold because of trauma to the cervix. Erosion of the cervix occurs when columnar epithelium replaces the squamous epithelium. Healing of the erosion takes place when the squamous epithelium grows back over the columnar extension. This causes the racemose glands to become permanently blocked, with a resulting hypertrophy of the entire cervix producing the picture of chronic cystic cervicitis. Whatever erosion exists at this stage depends upon the completion of regrowth of squamous epithelium. If the columnar epithelium is piled up so that the squamous epithelium cannot replace it, a papillary erosion with ectropion formation exists.

Hyams[12] states that in the treatment of endocervicitis progressive advances in electrotherapeutic measures have practically outmoded major surgery, for electrotherapy in skilled hands is relatively simple and is adequate in selected cases. However, it is dangerous unless the technique is thoroughly mastered. Too often, unhappy results are due not to the method of treatment but to lack of mechanical skill and errors in technical judgment. No one procedure now used fulfills all requirements for cure; age, degree of disease, presence or absence of complicating factors and previous treatment of the cervix influence the choice. The simplest and mildest form of electrosurgery, suitable for almost any general practitioner's office is electrochemical destruction by copper ionization. Electrothermal destruction by the coagulation and cutting current or electrocautery is reserved for more severe cases and requires more skill and experience and more elaborate accessories.

Copper Ion Transfer.—Copper "ionization" of the endocervix has been employed for many years. The rationale of its therapeutic action is that, from a copper electrode inserted into the cervix and connected to the positive pole of a galvanic generator, ions of copper are introduced and oxychloride of copper is formed which infiltrates the tissues and enters deeply into the crypts of the cervix. Depending upon the strength and duration of current flow, chemical destruction occurs in the superficial tissues while in the depth there are changes in the circulation.

Fig. 310.—Intracervical copper electrode (Tovey). The various sizes are $1\frac{1}{4}$ inches long. Nos. 16 to 28 French in diameter. The small rounded end enters, but will not pass the internal os, being prevented by the rounded shoulder.

The technique of treatment is as follows: A bare copper electrode of suitable size and shape, held in an insulated handle, is introduced under aseptic precautions into the cervix. The electrode is connected to the positive terminal of a galvanic generator or battery and held in position by packing in the vagina. The dispersing moist pad electrode, about 4 by 6 inches in size, is placed over the lower abdomen and connected to the negative pole. Commencing with a current within comfortable toleration (2 to 5 milliamperes), one gradually increases it to the limit of toleration (15 to 25 milliamperes) and continues this current from ten to twenty minutes. The only sensation of the patient is slight prickling under the abdominal electrode, when the current begins to flow or is too suddenly increased. From the first a blue discoloration appears around the electrode, due to copper deposition in the cervical crypts. At the end of treatment the electrode is usually firmly adherent to the cervical canal and cannot be withdrawn without force. In order to avoid trauma and bleeding one must reverse the flow of current for a few minutes. The action of the negative pole in the cervix produces hydrogen bubbles and a softening alkaline effect around the electrode which becomes loosened in the canal and can easily be withdrawn after a minute or two. One should learn to make the first treatment as thorough as possible. A second treatment is given after all reactive symptoms have subsided and the coagulum in the cervix has entirely separated. This takes usually one or two weeks. In well-selected and efficiently treated cases only a few treatments are necessary.

In reporting a series of cases of cervicitis treated at the author's department at the Polyclinic Hospital by copper ionization, the late D. W. Tovey,[16] a gynecologist of the hospital, stated that "The result is a lessening of the discharge; in a week or ten days it has disappeared, the cervix shrinks and after three or four treatments it appears normal. The infection, erosion, Nabothian cysts and discharge have disappeared. Large infected cervices that in the past required amputation shrink to normal."

FIG. 311.—Copper-tipped electrode in diseased cervix. (Tovey, Am. Jour. Obst. and Gynec.)

Electrocoagulation accomplishes destruction of diseased tissue by application of long-wave diathermy through an active electrode placed in contact with the cervix or cervical canal. Effects depend on intensity of current, duration of treatment and form of electrodes. Both bipolar and unipolar currents are used, and many special instruments have been devised for the purpose. Application varies; some use an inactive electrode on an external surface of the body, the active electrode in contact with the cervix. The Cherry[3] instrument incorporates both poles in one electrode. Amount of current ranges from 200 to 2200 milliamperes and duration from a few seconds to fifteen minutes. The majority maintain that the active electrode should be held in one position during treatment; a few advocate rotating the instrument. A whitish coagulation will appear all around the cervical electrode, and the slough of varying extent will separate in a few days, leaving a clean granulating surface. The end-result is a smooth pliable surface, free from scar formation. Unpleasant secondary hemorrhage, a large amount of scar formation and subsequent stenosis of the canal are the dangers in the hands of the less experienced and hence the preference for the much safer method of copper ionization for the average case.

Conization by the cutting high-frequency current has been devised by Hyams.[11] A fine cutting instrument, a metal tube with a platinum-iridium wire, is inserted into the cervix as the active electrode (Fig. 312); a dispersive electrode is connected to the other terminal. The instrument conforms to the spindle shape of the cervical canal, and the cutting element removes ⅛ inch endocervical lining with each revolution. The cut surface of tissue thus excised shows minimal coagulation and the specimen is satisfactory for microscopic study. In competent hands this instrument enables the "coring" and complete removal of the mucous lining of the cervical canal and its glands in a few minutes, with subsequent minimum scar tissue formation. The procedure can be repeated as often as deemed advisable.

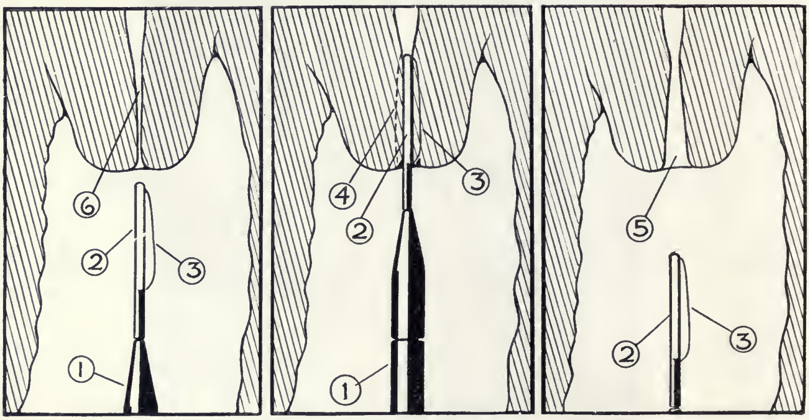

FIG. 312.—Conization of cervix. *1*, Insulated electrode handle. *2*, Insulated silicon tube. *3*, Tungsten wire cutting element. *4*, Portion of cervical lining being conized. *5*, Cervical canal after conization. *6*, Cervical canal before conization. (Courtesy of The Burdick Corp.)

In *cauterization*, the nasal tip and heavy duty cauteries destroy diseased tissue by direct contact and dissemination of heat; the amount of destruction depends on size of cautery tip and duration of application.

Cervical Erosion.—The troublesome result of chronic inflammatory conditions of the cervix usually heals after successful treatment of the underlying condition and the cessation of irritating discharge from the cervical glands. In stubborn cases one may use ultraviolet irradiation from a mercury vapor lamp with a local quartz applicator, producing a second- or third-degree erythema reaction over the lesion. For direct destruction electrodesiccation or electrocoagulation of the red and eroded areas may be applied. After the usual cleansing of the vagina and cervix the eroded surface is painted over with a 5 per cent solution of novocaine. Either a light desiccating or a stronger coagulating current is applied and every part of the erosion is fully treated. For prophylaxis of cervical cancer, it is advisable that every cervical lesion be cleared up by suitable measures.

Miscellaneous Conditions.—*Skenitis,* or the chronic infection of the small glands situated in the meatus of the urethra or just outside of it, is often responsible for the upkeep of a chronic gonorrhea. For its eradication after suitable local anesthesia the desiccating needle is introduced into the affected gland or glands and just enough current is turned on to coagulate the entire duct. *Chancroidal ulcers* in which no spirochetes have been found and localized areas of pruritus may be likewise effectively treated by electrodesiccation. In gonorrheal *Bartholinitis* the electrocautery can be used for incising the infected glands to evacuate the pus, subsequently the electrocutting loop can be applied to remove the infected glandular tissue.

NON-INFLAMMATORY CONDITIONS

Infantile Uterus With Stenosis of Cervix.—Negative galvanism is a time-honored means for gradually dilating a congenitally stenosed cervix. A metal cervical electrode is connected to the negative pole and a dispersing pad placed above the symphysis is connected to the positive pole. One should first employ an active electrode of smallest diameter, insert it under antiseptic precautions, turn on 1 to 3 milliamperes of current at first and increase its amount, always within comfortable toleration, to about 10 milliamperes. After a few minutes white bubbles appear all around the electrode in the cervix and it can be easily moved about. It should now be replaced by the electrode next in size, which easily slips in the softened cervical canal; a still larger electrode can be inserted perhaps once more, during a total treatment time of fifteen to twenty-five minutes. In the infantile uterus after the dilatation of the cervix, the last electrode should be left *in situ* and the surging faradic or sinusoidal current turned on, causing gentle contractions for from fifteen minutes to one-half hour. This treatment should be repeated twice a week for a period of several months, avoiding the proximity of menstrual periods.

Good results with this technique have been corroborated by Dannreuther[8] and Hirst.[10] The latter author observed the relief of chronic constipation following electrical stimulation of the uterus. Hirst concludes that the best treatment for constipation in women resisting ordinary methods is stimulation by the sinusoidal current. A large abdominal pad electrode is employed and the other electrode is placed either in the uterus, rectum or simply in the vagina. "In view of the demonstrated possibilities of this treatment, it seems strange that it should be ignored by most gynecologists."

Amenorrhea.—The possibility that the absence of menses may be due to pregnancy is always present and should, therefore, be definitely excluded before any physical measures are applied. In the functional type of amenorrhea occurring in young, undernourished (or dieting) girls and also in healthy well-nourished girls with ovarian dysfunction, general ultraviolet irradiations combined with transpelvic diathermy are advisable when the usual means of hygiene and medication are not fully satisfactory. Transpelvic galvanism or the static-wave current applied through the rectal electrode may also be considered as an adjunct to glandular therapy.

In secondary amenorrhea, such as may follow a sea voyage, mental excitement or a cold, the same measures will be of assistance. In married women vagino-abdominal diathermy may be employed or, still better, the interrupted sinusoidal or surging faradic current. For the latter a cylindrical vaginal electrode is employed and a large wet pad electrode is placed above the symphysis, 10 to 15 milliamperes of current are used for twenty minutes and the treatment is given twice a week. The same technique may be employed for building-up the muscles of the pelvic outlet in multiparæ and after repair operations of large tears.

Sterility.—Diathermy has been recommended in cases of sterility that appear to be due to genital hypoplasia or to disturbances in circulation, to a hematoma or inflammation according to Von Bodo.[18] This author employed simultaneous heating of the uterus and the ovaries by the abdomino-dorso-vaginal method. For the increase of the ovarian circulation he employed two electrodes on each side of the pelvis in the trochanteric region and a vaginal electrode. The author reports that out of 20 women treated by this method for a sufficiently long period (20 to 40 treatments for fifteen to thirty minutes) 14 subsequently became pregnant.

Dysmenorrhea.—In dysmenorrhea due to congenital non-development, gradual dilatation of the cervix by negative galvanism, as described, has given good results. Two to 10 milliamperes of current should be used for thirty minutes, twice a week. In the spasmodic type of dysmenorrhea the static-wave current has given considerable relief. A cylindrical metal electrode is inserted into the rectum and connected to the positive side of the static machine, the negative pole being grounded. The current is applied in increasing intensity, always to the point of tolerance. Dysmenorrhea in connection with pelvic adhesions, ovarian dysfunction or disease or uterine displacements, necessitates a combination of methods.

Menopausal Syndromes.—In conditions not benefited by estrogenic substances, intrapelvic or intracervical diathermy may be applied. Robinson extols the effect of diathermy on menopausal disturbances, especially menopausal arthritis, due at times to the effect of a pelvic focus of infection.

Minor Surface Growths.—For the treatment of superficial benign growths on the vulva, such as condylomata, urethral caruncles, cysts or of the Nabothian glands, electrodesiccation offers an ideal method. It can be applied always without general anesthesia and generally without even a local one. For the latter purpose infiltrating the base of the new growth with a few drops of 2 per cent novocaine is sufficient.

Electrosurgical biopsy, as discussed in Chapter XIII is a very useful procedure in gynecological diagnosis.

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CHAPTER XXXI

GENITO-URINARY CONDITIONS

General Considerations. Technique. Nephritis. Tuberculosis of the Kidney. Renal Colic. Cystitis. Incontinence of Urine. Prostatitis and Seminal Vesiculitis. Prostatism. Gonorrheal Epididymitis. Tuberculous Epididymitis. Gonorrheal Urethritis. Calcified Deposits in Corpora Cavernosa. Stricture of Urethra. Electrosurgery in Urology.

General Considerations.—Physical measures are useful adjuncts in treatment of a number of genito-urinary conditions. A complete diagnosis arrived at by tests of the urine, rectal and possibly urethroscopic examination is essential in any doubtful case before physical therapy is undertaken.

Thermal measures are employed in the form of local heating by hot sitz baths, hot water and hot air applications, and short-wave and long-wave diathermy; systemic heating by electric light cabinets and the various methods of hyperpyrexia. They serve for treatment of subacute and chronic inflammations, especially in gonorrheal infections. Research work in fever therapy (Chapter XI) demonstrated varying heat resistance of the many strains of gonococci. In the majority of cases the chief virtue of local heat therapy, as it is generally employed, seems to be to create an unfavorable condition for the viability of the gonococcus. There is ample clinical proof that in complications of gonorrhea local use of diathermy is quite effective in many cases and there is no need for the routine use of fever therapy in all cases.

Electrothermal destruction of tissues finds an increasing employment in surgical disorders of the genito-urinary tract because it facilitates the rapid and gentle handling of tissues, lessens or eliminates bleeding and operative shock and after-pain.

Ultraviolet irradiation is indicated in tuberculosis of the urogenital tract or in fistulæ or slow healing wounds following operations for urogenital tuberculosis.

Mechanical measures, in the form of massage or by currents of low frequency for muscle stimulation serve as adjuncts in the treatment of certain chronic inflammatory conditions where local stasis is a predominant symptom. Preliminary deep heating makes mechanical measures more effective.

Electrodes and Technique.—For *prostatic diathermy* electrodes with an all-metal end and with a slight depression to fit the bulk of the prostate are preferable to those with only a small metallic contact area. These electrodes can be employed for long-wave diathermy or short-wave diathermy with the direct contact method. They should be inserted with the tip well lubricated with petrolatum, by slow, turning motions, into the anal opening and gradually pushed about 2 to 3 inches into the rectum, while the patient lies on his side. He is then told to turn on his back, while the prostatic electrode is propped up in its position by a few sandbags; a dispersive electrode, 4 by 5 inches in size, is placed just above the symphysis. The current is turned on gradually, never causing any ache or burning sensation; usually from 1000 to 1200 milliamperes can be well tolerated. The current should be flowing for at least twenty-five minutes. Cumberbatch, with an electrode containing a thermometer, found that most patients could stand temperatures of 111° to 112° F., which corresponds to 3° or 4° F. lower temperature in the interior of the prostate.

Pushing the prostatic electrode somewhat higher up on either side and moving the indifferent electrode somewhat further up from the symphysis usually puts either of the *seminal vesicles* in the direct path of the current and the same technique is used.

Short-wave diathermy to the perineum, prostate and seminal vesicles can be applied by the electromagnetic field method with a pancake coil covered by suitable spacing and a pillow; all this is placed on a wooden chair and the patient sits on the pillow.

For short-wave diathermy to the *epididymis* and *testis* air-spaced electrodes serve conveniently. For long-wave diathermy the contour and consistency of the scrotum make exact adaptation of electrodes difficult. The standard method is a clamp-holder with electrodes of suitable size (Fig. 313) which are adapted against the sides of the scrotum. The current flow must be started very gently and usually kept between 300 to 400 milliamperes.

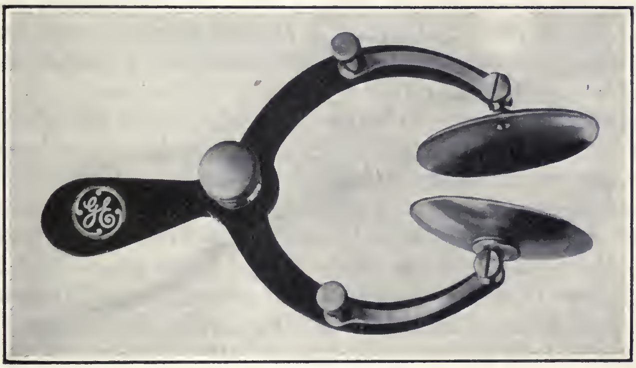

FIG. 313.—Scrotal electrode. (Courtesy of General Electric *X*-ray Corporation.)

Both short- and long-wave diathermy may be applied to the penis by external electrodes, as described later in this chapter.

Nephritis.—It is a physiologically established fact that external heating procedures cause a simultaneous dilatation of the blood-vessels of the skin and the kidneys and thus increase the excretory function of the latter. Local heating of the kidneys becomes effective either by direct thermal reflex *via* the same spinal segment or by the secondary skin effect of prolonged heating. In deficient kidney function external heating increases diuresis as well as the elimination of salt and nitrogen. While some authors consider the stimulation of kidney function by sweating procedures as most important, others stress the increased function of the skin by such procedures and the vicarious removal of nitrogenous substances through the skin.

Pemberton[9] recommends in nephritic conditions accompanied by marked laboratory evidences of retention of nitrogen, or by clinical evidences which suggest the toxemia consequent to such retention, a sweating process; he believes that in the presence of edema or anasarca of renal origin, the hot pack or general body bake may at times result in significant consequences in the form of loss of fluid from the tissues almost from the start. The particular manner in which heat is systemically applied in nephritis is of secondary importance; the simplest form and one that can be carried out in any household, is the hot pack. General heating from large incandescent lamps or an electric light cabinet may also serve. (Chapter XVI.)

Diathermy to the kidneys has been recommended by German clinicians in threatening uremia, especially anuria no matter of what origin. They also favor its application in subacute and chronic nephritis. Eppinger, Rein and Schurmeyer[3] report on the use of diathermy for two to four hours daily in acute glomerulonephritis, and attribute the favorable results in all but the most severe cases to increase capillarization of the glomeruli. Corroborative evidence of increased diuresis and decrease of albuminuria is offered by Ewig[4] and others. Short-wave diathermy is equally applicable and according to Rausch[10] on account of its more intense deep effect is additionally indicated in nephrosclerosis, where it is claimed to result in a more lasting lowering of blood-pressure than long-wave diathermy.

In applying diathermy to the kidneys, a smaller, active electrode corresponding in shape and size with one or both kidneys is placed posteriorly and a large dispersive electrode about 8 by 10 inches is placed on the upper abdomen. Short-wave diathermy is applied similarly with one smaller condenser electrode over one or two kidneys and a larger one in front with suitable spacing under both.

For a report on the use of short-wave diathermy in nephrosclerosis and hypertension see Chapter XXIV. Good results have also been reported in fistulas after nephrectomy and in cystopyelitis.

In the technique of short-wave diathermy to the kidney a small condenser pad electrode is applied over one or two kidneys and a larger one in front with suitable spacing under both. More generalized heating in threatening uremia can be done by a disc or coil electrode centered above the upper part of the abdomen for the first half of the treatment and over the lower part of the back for the second half. Between the skin and the disc or coil there is introduced the equivalent of six thicknesses of turkish toweling. The patient is covered with sheets or blankets, to induce sweating and to retain heat. At intervals, the perspiration is wiped off with suitable soft towels. Rectal temperature is taken every fifteen minutes and should not exceed 102° to 103° F. If possible, the treatments are gradually increased to one hour twice daily and, if advisable, a third application is made at midnight.

Tuberculosis of the Kidney.—This is usually unilateral and offers an indication for nephrectomy. As a palliative treatment diathermy to the affected kidney has been recommended. In operative cases there is a tendency for a breakdown of the wound and formation of fistula. In these cases artificial ultraviolet irradiation or natural heliotherapy is most effective in speeding up healing (Wang[13]). Short-wave diathermy has been recommended for the same purpose.

Renal Colic.—In renal colic due to stones in the pelvis of the kidney local heat applications and hot-tub baths often give marked relief and enable cutting down or omitting morphine injections. The author has seen dramatic relief in a few cases by diathermy. In stone impaction in the ureter which has been located by roentgen-rays it may be possible to bring about enough deep relaxation by diathermy or short-wave diathermy to relax the spasm and allow the passage of the stone.

Cystitis.—In acute cases luminous heat or infrared radiation to the suprapubic region serves to relieve pain and draw the blood to the surface from the congested parts. It should be applied fairly continuously at first. Diathermy with one electrode over the symphysis and another under the sacrum may be employed in resistant cases.

Incontinence of Urine.—Incontinence of urine due to an atonic bladder or sphincter after operations may be treated by the surging faradic current, with electrodes above the symphysis and under the sacrum or with the static-wave current, a cylindrical electrode in the rectum or a plate above the symphysis.

Prostatitis and Seminal Vesiculitis.—Inflammations of these organs are in the large percentage of cases of gonorrhcal origin. Diathermy is the choice of management in acute cases which are not suitable for chemotherapy and in subacute or chronic cases. Harrison[5] states it far surpasses the time-honored methods of applying heat by sitz baths and rectal douches. It actively directs heat to the prostate with a higher temperature which is more uniform and over a longer period of time. It usually brings quick relief of the distressing symptoms and reduces the size of the gland rapidly. Patients of course must have bed rest, possibly in a hospital. Daily diathermy treatments for thirty to forty minutes are advisable with an active electrode of suitable size and shape introduced into the rectum in close relation to the posterior surface of the prostate, previously palpated. The current must be started gently, for often the pain is increased at first, due to the added hyperemia in the already distended parts; this initial discomfort, as a rule, soon subsides and patients feel more comfortable than before the treatment. Up to 1200 milliamperes of current can be usually comfortably tolerated.

The success of this procedure depends altogether upon the fact as to whether there is proper drainage from the prostate and seminal vesicles, the only indication of which is the marked improvement of the condition. Treatments should not be continued if there is more elevation of temperature and fluctuation of the prostate, because this indicates pus formation in that organ. Short-wave diathermy by the inductance coil technique was applied by Hibbs and Osborne[6] in chronic prostatitis, who found first a moderate exacerbation of subjective symptoms in the more resistant cases, as shown by slight fever and leukocytosis which continued into the fifth week of treatment, at which time there was a complete remission of subjective complaints, reduced leukocyte count, lowered temperature, and general appearance of well-being. At the end of the series consisting of an average of ten treatments these patients showed a definitely reduced pus content of expressed secretion and on subsequent re-examination showed a continued small amount of pus cells with increased lecithin content.

For mechanical effects in chronic prostatitis, the static wave current, if available, is a most efficient and pleasantly tolerated method.

Lacking a static machine, the sinusoidal or the interrupted galvanic current may be applied through a metal electrode in the rectum and a wet-pad electrode over the symphysis. The combination of diathermy with the sinusoidal current is useful in selected cases. (See Chapter XI.)

Prostatism.—One of the most frequent troubles in men past the age of fifty years is prostatism, that disturbance of the function of the prostate that manifests itself by a variety of local symptoms, such as slow and frequent micturition, dribbling, frequent urination at night, possibly followed by complications in the genito-urinary tract; of general symptoms there may be general debility, loss of sleep, loss of memory, chronic constipation and impotency. These may be due to a variety of causes: chronic inflammatory changes in the prostate, congestion and infiltration or actual hyperplasia, fibrosis and myomatous enlargement, calcareous or neoplastic formations. In any set of such symptoms it is obviously of first importance to ascertain by all available means the exact underlying pathology. There is histological and pathological evidence for the fact that in many cases the so-called hypertrophied prostate is only an inflammatory enlargement due to a variety of causes (old infection, stasis, sedentary habits, etc.). When such a patient is operated upon by the usual two-step prostatectomy the first step consists only of a suprapubic incision of the bladder. This operation only insures improved drainage of the urine, and yet the subsequent rapid shrinking of the large hypertrophied prostate is remarkable, leaving only a small fibrotic gland to enucleate. This corroborates the empirical experience that some cases of enlarged prostate are readily amenable to treatment by physical measures. According to Pedersen[8] the best results may be expected in cases where congestion of the prostate is the predominating factor, grafted on underlying simple hypertrophy.

With diathermy or the static-wave current the author has seen elderly patients suffering from painful and irritating prostatic disturbance improve steadily.

Lack of prompt and progressive improvement after a series of treatments, especially as measured by an improvement in the residual urine may be taken as evidence that the pathological changes in the prostate are of a more permanent nature. On the other hand, even in a case diagnosed as an organic hypertrophy or adenoma, treatment by the static-wave current or diathermy may be worth trying because, by removing part of the accompanying edema and infiltration a satisfactory measure of relief may often be achieved and operation postponed until a more suitable time.

Gonorrheal Epididymitis.—Diathermy is of almost specific value in chemoresistant cases, for in most instances it relieves pain and quite promptly aborts the attack. The techniques of application have been described. It is advisable to apply half-hour treatments with the scrotum kept elevated by the usual adhesive bridge method. The result of the treatment is shown by the subsidence of pain, swelling and tenderness. Treatment should be repeated daily until the acute condition is entirely relieved. Rest and wearing a suspensory are essential; in severe cases the patient must stay in bed and the testicle be kept constantly elevated.

In patients with much edema and tenderness treatment can be started with luminous heat radiation for one-half to one hour several times a day. In resistant cases fever therapy may serve as a last resort.

Gonorrheal Urethritis.—The results of modern chemotherapy have made the discussion about the various techniques of local diathermy in this condition largely academic.

Reports on fever therapy in acute gonorrheal cases showed a high percentage of negative cultures in patients with single ten-hour sessions (See Chapter XII.)

Tuberculous Epididymitis.—The combination of general irradiation from a mercury vapor or carbon arc lamp with some local irradiation often relieves pain and swelling and may lead to gradual absorption without aspiration or more extensive surgery. In cases where surgical removal of the epididymis becomes a necessity, in the after-treatment ultraviolet irradiation will speed up the healing of sinuses.

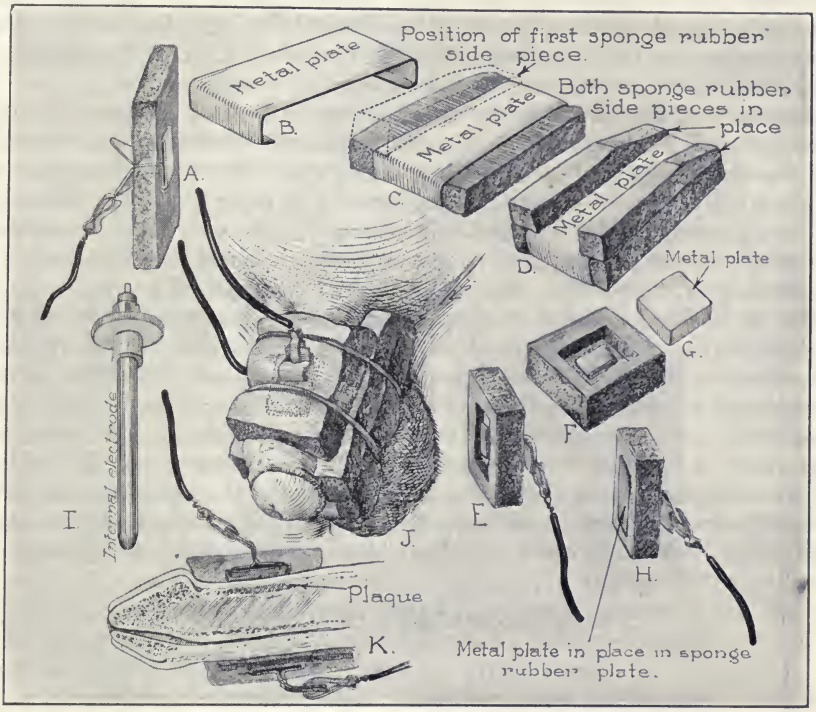

FIG. 314.—Diathermy to penis. Pair of penile electrodes made from sponge rubber and block tin. Large electrode lies below and supports phallus, while small one is placed directly over plaque. Electrodes held in place with rubber bands, *J* and *K*. If edge of tin comes in contact with skin, it will cause a burn, hence in the large one the ends must be bent under rubber and sides covered with "side boards" of rubber, *A*, *D;* in small one, tin can be bent to bury edges in excavation in rubber, *E*, *H*. Internal electrode, *I*, is made from female sound, a rubber cuff controlling depth of insertion, with electrical connection at exposed end, sometimes helpful in addition to, or in place of, ventral electrode, *D*. Metal disc of small electrode should be same size as plaque and placed directly over it. (Courtesy of Dr. M. B. Wesson.)

Calcified Deposits in Corpora Cavernosa.—Calcified plaques in the sheath of the erectile tissues of the penis are the result of a slowly progressing chronic inflammation of uncertain origin, possibly rheumatic. This condition has also been described as Peyronie's disease or plastic induration. There are first some painless areas of induration which interfere with erection and later cause a marked curvation of the organ. Since diathermy affects the absorption of calcified deposits in other locations, notably in bursæ it suggests itself for this condition so notoriously resistant to all other forms of treatment. The author has seen in several cases much improvement corroborated by roentgen-ray evidence.

The technique of treatment is to apply two narrow strips (about ½ inch) of diathermy metal opposite each other along the entire length of the penis and hold them by smaller sandbags under and above the organ; heating of comfortable toleration (from 300 to 500 M) is administered for thirty minutes to one hour two or three times a week. Either long- or short-wave apparatus may be used. (Contact plate technique with the latter.) Heating may be also administered by small condenser pads held on either side of the penis, the amount of heat energy applied controlled by the feeling of comfortable warmth. Wesson[14] has recently also reported encouraging results in several cases by diathermy (Fig. 314), combined with administration of disodium phosphate by mouth.

Stricture of the Urethra.—A method very little used nowadays is the dissolution of scar tissue in the urethra by negative galvanism, introduced by Newman many years ago. An olive tip two sizes larger than the stricture is placed on an insulated handle and inserted so it just engages the stricture. It is connected to the negative pole of a galvanic source and a wet-pad dispersive electrode placed over the abdomen or under the buttocks is connected to the positive pole. The current is increased gradually so as never to cause a decided burning sensation; the maximum amount will depend on the relative size of the olive. The current flow is kept up until the olive tip slips of its own weight past the obstruction. This takes about five to ten minutes. The treatment is repeated with olives of increasing size, until a No. 28 French sound can be easily passed. Urethroscopic examination in cases thus treated has shown the increase of the caliber of the urethra and the changed appearance of the texture of the mucosa. Uthoff[12] reported very satisfactory results with this method in organic or definitely fibrotic strictures and Beck[1] has corroborated these results.

ELECTROSURGERY IN UROLOGY

By DANIEL A. SINCLAIR, M.D.

PROFESSOR OF UROLOGY, POLYCLINIC MEDICAL SCHOOL AND HOSPITAL, NEW YORK CITY

The surgical application of electricity in urology has, in recent years, been extended to resection of the enlarged prostate gland with gratifying results. It has been, and still is, extensively and successfully employed, in the treatment of benign papilloma of the bladder, cystitis cystica, ureterocele and for the enlargement of the ureteral orifices to facilitate the passage of impacted calculi, as well as in malignant non-infiltrating papillary carcinoma of the bladder. All of these procedures are carried out by the transurethral route, through the cystoscope, using either the coagulating or cutting current or a combination of both.

Meatotomy, when indicated, especially in balanic hypospadias, where the enlargement should be made at the expense of the tissue of the glans penis, is happily changed from an often bloody and annoying operation to one of safety and permanency by the cutting current.

Non-tuberculous obstructions, such as chronic inflammatory vesical neck contracture or bars, are most amenable to electrosurgical resection by the transurethral route.

Epididymectomy for tuberculosis of the epididymis is most satisfactorily accomplished by the fine and neat dissection, afforded by the cutting current, using an ordinary cambric needle attachment.

Verruca acuminata on and about the glans penis may be completely destroyed by electrodesiccation.

Papillary growths of the bladder, when extensive, multiple, benign or malignant, and *infiltrating carcinomata of the bladder*, are indications for open operation by means of a suprapubic cystotomy. In such a procedure, the scalpel is dispensed with, the usual incision through skin and fascia being made by the cutting current of the proper strength, which cuts and coagulates at the same time. If there be an active bleeding-point, it may be controlled by coagulation. After the separation of the recti muscles by the fingers, and the stripping upward of the prevesical fat and peritoneum with the gauze-covered finger, the bladder is ready for opening, which is accomplished by severing freely all of its coats. The situation of the growth to be resected having been determined by cystoscopy, sufficient mobilization of the viscus is carried out, so that the growth proper is not cut through when opening the bladder. The growth, including the wall of the bladder at its base, and a portion of apparently healthy bladder tissue surrounding it, is now excised. The margin of healthy bladder wall should be about $\frac{1}{2}$ inch in width. Smaller scattered growths or suspicious-looking spots may be treated by the coagulating current.

The types of *adenomatous prostatic obstruction* that are suitable for transurethral electrosurgery are: moderate middle lobe enlargement, moderate unilateral or bilateral intraurethral enlargement, or a combination of all three types.

Spinal anesthesia is ideal for resection, and unless otherwise contraindicated should be employed. Resection of the obstructing portion of the prostate gland is performed transurethrally. The McCarthy-Wappler unit is most efficient and satisfactory for this type of operation. The sheath of the endoscope is made of bakelite, which is a non-conductor of electricity. It is fitted with an obturator to facilitate its passage into the posterior urethra and bladder.

After obtaining a clear field by irrigation with distilled water, which solution only should be used, the telescope and cutting element are placed in position.

The verumontanum is now visualized, as it is a valuable landmark and provides proper orientation for the operator. It must not be injured. Under continuous irrigation, only the obstructing prostatic lobes above it are to be resected. After each piece of tissue is removed, the resulting groove is inspected for bleeding points, and over any bleeding spot the same loop electrode is passed, now carrying the coagulating current, instantly obtained by the operator placing his foot on the coagulating button of the foot switch. Control of bleeding is an all-important point in the technique and should be thorough after each piece of tissue is cut away.

In the case of *carcinoma of the prostate gland*, when obstructive symptoms develop, resection is indicated as a palliative procedure. Heretofore, in this type of pathology, a patient, when he could not empty his bladder, was forced to lead a catheter life, and when this became impractical or impossible a suprapubic cystotomy and permanent drainage was instituted as a last resort. The selection of suitable types of enlargement, as outlined above, the visual control of the operative field through the cystoscope, the efficient cutting power of the current and the hemostasis accomplished by the application of the coagulating current make this operation a safe one. However, good urological judgment, the result of experience in prostatic and bladder surgery, must decide the method of procedure, as no hard and fast rules can be laid down for the sure guidance of inexperienced instrumenteurs.

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CHAPTER XXXII

PROCTOLOGICAL CONDITIONS

By R. V. GORSCH, M.D.

CLINICAL PROFESSOR OF PROCTOLOGY, NEW YORK POLYCLINIC MEDICAL SCHOOL AND HOSPITAL

Hemorrhoids. Fistula in Ano. Fissure in Ano. Stricture of the Rectum and Anal Canal. Polypi of the Rectum and Colon. Biopsy. Proctitis. Pruritus Ani. Coccygodynia. Neuralgia, Hysteria of Rectum. Tuberculous Peritonitis, Enteritis and Anorectal Tuberculosis. Cancer of the Rectum.

In the proctologic field a review of the literature reveals that the indications and limitations of physical therapeutic measures have become more sharply defined and their use has become somewhat restricted to definite conditions.

Electrothermic surgical methods offer certain advantages and simplify the technique in many proctological surgical procedures, *e. g.:* They minimize hemorrhage and prevent the lymphatic spread of the disease. The removal of malignant or benign tumors, large papillæ, infected deep crypts, division of strictures, excision of pilonidal sinuses may be carried out with the cutting current or coagulation. Hence electrosurgery in selected cases widens the scope and safety of proctological surgery.

There still remains a not unconsiderable number of proctologic patients who fail to receive the benefits of physical therapy. A closer liaison between general practitioner, physiotherapist and proctologist seems desirable.

Hemorrhoids.—The electrotherapeutic treatment of hemorrhoids is either palliative or radical, depending in great measure on the type of piles, the general condition of the patient, the exciting causes and the coexistence of other pathological changes which are commonly enough overlooked. Carcinoma higher up in the bowel should be particularly ruled out.

Hemorrhoids are broadly classified into external and internal. The external are further subdivided into external thrombotic and true external piles, which are comparatively rare. External thrombotic piles are actually not hemorrhoids but merely hematomas of varying size in the perianal tissues. They are preferably removed with scissors or scalpel under local infiltration anesthesia. When complicated or associated with strangulated internal hemorrhoids they should be removed with the internal hemorrhoids. When their surgical removal is considered inadvisable, the injection of an oil soluble anesthetic (anucaine), hot sitz baths and then local application of heat, diathermy are valuable palliative measures.

The infrequent true external piles which consist of dilatation or varicosities of the external hemorrhoidal plexus of veins are usually the result of prolonged constipation with straining at stool. Their structure represents an exaggeration of the normal physiological venous dilatation occurring in these veins during defecation. They are, therefore, only prominent during the activity of the anal canal and do not usually require surgical intervention except in the rare advanced case in which a large coronal mass of enlarged veins surrounds the anus externally.

Internal hemorrhoids are the common type and they are quite frequently related etiologically to other diseases, such as cirrhosis of the liver with portal congestion, chronic constipation, colitis, enteroptosis, uterine tumors and retroversion, enlarged prostate, spasmodic sphincters, obstructive valves, strictures of the rectum and urethra. In fact, anything which causes an abnormal increase in the venous pressure of the hemorrhoidal plexus predisposes to hemorrhoidal disease.

Many of these associated conditions may be benefited by appropriate physical measures. For example, portal congestion is relieved by diathermy to the liver with a salutary effect on the hemorrhoids, using the technique as described for cholecystitis. Chronic constipation may also be benefited by other physical methods enumerated in Chapter XXIV. Genito-urinary conditions responsible for hemorrhoidal stasis are frequently amenable to diathermy or electrosurgical or other modalities described in the previous chapter.

Electrotherapeutic measures should only be applied to simple uncomplicated cases of internal hemorrhoids. Any one of the following modalities may be applicable to a given case of hemorrhoids and the practice of restricting oneself to one form of treatment in all cases is distinctly undesirable.

Medical Diathermy.—In selected cases of early varicosities without prolapse and little bleeding medical diathermy may be used with good results, as reported by Kobak.[5] It is of particular value in those cases of excessive scarring or stricture of the anal canal which are sometimes quite painful and obstruct to varying degrees the evacuation of the fecal mass. The technique of application is described in Chapter XI. The active electrode should preferably be tapered and fit the anal canal without undue pain or trauma. The author frequently uses as an active electrode a small Brinkerhoff speculum which affords some degree of dilatation as the sphincters relax from the salutary effects of the heat. A current flow from 1000 to 1500 milliamperes should be continued over a period of twenty to thirty minutes, twice a week. The ordinary metal rectal dilators make useful active electrodes and are self-retaining.

Diathermy may also prove useful in aiding the decongestive process of hemorrhoids following pregnancy, and it may likewise afford considerable relief in those sometimes intractable cases of anal neuralgia, sphincteralgia and coccygodynia from obscure causes frequently associated with hemorrhoids. Insulated electrodes may be preferable when short-wave diathermy is used.

Electrosurgery.—(*a*) *Electrodesiccation.*—The usual technique consists of applying a needle-point electrode connected to the high-voltage (Oudin) terminal either close to the hemorrhoid or at a sparking distance from its surface; this is similar to the technique in removing small tumors of the skin. Subsequent drying, shrinkage and sloughing occurs, depending on the strength of the current and the depth of its penetration, which in large hemorrhoids must be considerable. The hemorrhoidal area must be, of course, anesthetized sufficiently to freely expose the hemorrhoids. The injection of anucaine as advocated by the writer greatly facilitates the relaxation of the sphincters and prevents much of the after-pain. All of the piles should usually be treated at one sitting to avoid the repetition of injecting the anesthetic solutions into inflamed tissues. A very strong Oudin current may actually char or coagulate the tissues, particularly epithelial or mucous membrane and the procedure may be incorrectly thought to be desiccation. Electrodesiccation should not be used in advanced cases of hemorrhoids or those complicated by other ano-rectal pathology.

(*b*) *Electrocoagulation.*—Electrocoagulation may be performed with a single pointed electrode as an active electrode and a large dispersive electrode is used on the abdomen or back. In this procedure the same technique may be used as in desiccation: either sparking or plunging the electrode into the depth of the hemorrhoid. Obviously the depth of current penetration is difficult to control.

In the biterminal procedure of coagulation a biterminal active electrode is employed and a dispersive electrode is not necessary. With the idea of confining the depth of coagulation several biterminal electrodes have been devised, a popular example of which is the Bierman clamp. This clamp consists essentially of two active parallel insulated electrodes buried in the insulated jaw of the clamp.

The technique of the biterminal clamp method consists in freely and firmly grasping the pile along its basis parallel to the bowel, just as in the usual clamp and cautery operation. The current is controlled through a foot switch and its strength and duration determined by the previous experience of the operator. The neophyte should experiment with strips of meat beforehand. Sufficient current strength is used to coagulate the entire base of the pile. Theoretically the desired degree of coagulation is determined by the tissue turning to a light gray color; actually the tissue cannot be seen between the jaws of the clamp. The portion of the pile above the clamp is removed with a cutting loop or scissors. Each of the hemorrhoids is removed in turn and a small piece of petrolatum gauze inserted into the rectum. The skin should never be included in the jaws of the clamp. If excessive skin tabs are present with the piles they should be cut away or undercut up to the mucous membrane at the beginning of the pile and removed *en masse* with it. It is important that the incision freeing the skin tag should be made sufficiently deep so as to include the external hemorrhoidal plexus of veins and their supporting stroma which commonly shares in the hyperplasia of the veins and is an important part of the pathology.

The patient is prepared by catharsis and sedation as in the usual hemorrhoidal operations. The anesthesia may be local infiltration of novocaine, 1 per cent, or, better, the injection of anucaine supplemented by novocaine. Anucaine will give decidedly better relaxation of the sphincters which is essential in using a cumbersome clamp and the after-pain will also be decidedly less.

The postoperative treatment consists in the application of hot compresses of boric acid or saline solution, appropriate sedation and the local application of soothing ointments.

(*c*) *Cutting Current.*—The cutting current has no place in the surgical treatment of any type of hemorrhoid. The electric snare has been used and recommended for the removal of internal hemorrhoids. However, the technique will not be described because the author considers the method uncertain and unsurgical. Its use has resulted in large ulcerated areas, followed by excessive scarring, secondary hemorrhage and stricture of the anus.

Critique.—Theoretically surgical diathermy and other electrical methods would appear to be ideal in the removal of hemorrhoids, but in practice these methods are distinctly less satisfactory than a clean surgical ligature operation (Gorsch[3]). The vaunted advantages of these methods being ambulatory or an office procedure and bloodless can only be offered to a few selected cases of uncomplicated internal hemorrhoids, since the vast majority of them are complicated with other pathological changes. Hemorrhoidectomy is not and should not be an office procedure. A hemorrhoidectomy of even moderate degree demands a few days' rest in bed for the comfort and safety of the patient and for the prevention and immediate treatment of complications. It, therefore, cannot be considered an ambulatory method. The fact that electrical methods may be bloodless is erroneously thought to be a decided advantage. Actually the majority of the cases of hemorrhoids have chronic submucosal infections, with infected crypts and muscular glands and large chronically infected skin tabs. Removal of these and proper subsequent drainage at the base of the hemorrhoid is essential to a complete hemorrhoidectomy and satisfactory end-result. Moreover the blood loss in a properly performed surgical operation for hemorrhoids is quite negligible.

Electrothermal surgical methods in the hands of the inexperienced have led to excessive scarring with indolent ulcerations, burrowing infection, deep sloughing, secondary hemorrhage and an unwarranted amount of postoperative pain. In carefully selected cases and for palliation and in experienced hands the results may be satisfactory.

Surgical Galvanism.—Surgical galvanism or electrolysis (Chapter VIII) depends on the deposition of caustic ions into the hemorrhoid and its supporting connective-tissue stroma. An inflammatory reaction ensues which after final resolution and absorption of the inflammatory exudate supposedly shrinks up the pile.

The technique of destruction by negative galvanism as advocated by Keesey[4] is as follows: An extra long especially constructed steel needle is used as the active electrode from the negative pole; it is inserted in the longitudinal axis of the lumen of the hemorrhoidal vein, care being taken not to transfix it. A current from 10 to 15 milliamperes is applied for several minutes, until the entire tumor turns a characteristic dark red or black color. It is claimed that following treatment the thrombosed mass usually is absorbed with very little pain.

The negative galvanic method is recommended only for internal hemorrhoids and is not applicable for those covered with skin. Non-protruding hemorrhoids must be treated after adequate exposure through a speculum. No local anesthesia is employed, for if one succeeds in inserting the needle into the lumen of a vein, as Keesey expects, there should be no undue sensation; a burning pain should indicate the need for shifting and reinsertion of the needle-point. As a matter of fact the relative lack of pain, in our opinion, may be much better explained by the insertion above the papillary line where there is a comparative lack of sensation of pain. Large hemorrhoids should be treated by several sessions about every third day, treating separate parts of the tumor with a current flow of not over five minutes each time. Keesey estimates about six treatments required for the average large hemorrhoidal mass, and he claims that postoperative recovery is smooth, hemorrhage never occurs and recurrence is rare.

Further experience in competent hands is needed to determine the definite value of this method.

Fistula In Ano.—Physical measures play a minor rôle in anorectal fistula. Iontophoresis has been used but is of questionable value. The roentgen-ray has been highly recommended by French authors and in extensive fistulæ with multiple openings, it may perhaps be of some value. We have had no experience with this method and it does not appear to be popular in the United States. The use of roentgen-rays around the genitalia has obvious limitations.

In the surgical treatment the cutting current would theoretically appear to offer decided advantages in the excision or incision of fistulæ. However, in our experience, the electric knife cuts with such rapidity that it is difficult to judge whether one is cutting through diseased or normal tissue, a most important consideration for good fistula surgery. We still find the scalpel the most sensitive effective weapon for this type of surgery. Moreover the dissection of tracts close to the rectal wall with the cutting current is done with considerable risk of immediate or remote perforation. The actual cautery is preferred by some in the tuberculous variety of fistula when this can be determined beforehand.

Fissure In Ano.—Uncomplicated cases of fissure in ano which commonly result from the passage of hard stools may be treated successfully by electrotherapeutic measures. The severe pain, spasm and soreness often accompanying fissure may be relieved by medical diathermy applied to the anal musculature. A small metallic rectal dilator may be used as the active electrode. The application should be continued for from fifteen to twenty minutes with a current strength of from 1000 to 1500 milliamperes. Complicated fissures secondary to hemorrhoids or fistulas should be treated surgically.

The static-wave current or the Oudin current may also be used with the usual percutaneous application.

Chronic constipation is so commonly associated with fissure that electrotherapeutic measures directed to its alleviation should be enjoined.

Stricture of the Rectum and Anal Canal.—Medical diathermy has proved to be of marked benefit in those cases of rectal stricture in which surgical intervention is either contraindicated, refused or unwarranted because of the nature and extent of the pathological process. *Lymphogranuloma inguinale,* the fourth venereal disease or, better termed, lymphopathia venerea has now assumed a particularly important etiological rôle in the vast majority of rectal strictures, particularly in women. Medical diathermy has unquestionably saved many of these patients the disagreeable stigmata of a colostomy. It has also materially lessened the rectal discharge always present in stricture, reduced the pain and tenesmus and has made these unfortunates decidedly more comfortable.

Diathermy has also been recommended as a postoperative therapeutic measure in those cases in which the walls of the stricture have been freed by incisions into the ischio-rectal fossa.

The technique of diathermy application in these cases is sometimes quite difficult and exacting; the treatment entails the skilful introduction of a metallic electrode through spastic anal sphincters and through a long stricture, the lumen of which is quite irregular and variable in caliber. It is essential that the electrode employed should extend the entire length of the stricture, since the entire stricture must be treated; furthermore, as the stricture becomes gradually dilated larger electrodes must be used, either during the same treatment or in subsequent treatments. For this reason it is strongly advisable that treatments be carried on through a close coöperation of the proctologist and the physical therapist; the former should preferably pass the electrodes during the first few treatments. Patience and close application are necessary and the treatment must be extended over a long period of time at regular intervals. The gratifying results make this effort worthwhile.

Each treatment should continue for at least one-half hour with a current strength of 1000 to 1500 milliamperes, according to comfortable toleration.

The type of electrode to be preferred is shown in Figure 169; these electrodes are available in increasing size. In small-caliber strictures large urethral sounds may be usefully employed.

Anal strictures usually respond to surgical treatment; however if this be contraindicated, diathermy may be helpful. Increasing sized metal Pratt dilators make suitable electrodes for the anal canal; for the rectum, the simple straight graduated tubular electrodes devised by Frankfeldt are quite satisfactory.

Polypi of the Rectum and Colon.—Under the generic name of polypi are included a number of usually benign tumors of various histological structure. They predominate in the rectum and sigmoid, and since they are all potentially malignant, particularly the adenomata in adults, they demand prompt eradication.

Surgical diathermy is decidedly the method of choice in the removal of these tumors and may be employed with excellent results. The sphincters should be relaxed either with the injection of anucaine or novocaine and the patient placed either in the Hanes or raised later to Sims' position. A large proctoscope which is preferably insulated is introduced and the tumor removed by biterminal coagulation with the Gorsch suction electrode, which removes the smoke and keeps the field clear. The base of the tumor should be completely destroyed, leaving a healthy granulating surface after the tissue has sloughed away. This procedure is particularly useful in the pedunculated polypi usually found in children. It may be further advisable when malignancy is suspected to coagulate around the periphery of the pedicle to prevent spreading through the immediate adjacent lymph vessels as much as possible.

Tumors higher in the rectum or in the sigmoid and usually found in adults are frequently already malignant and often present a difficult problem. If pedunculated they may be destroyed by fulgurating or coagulating the pedicle as previously described. Their removal may be more easily carried out with a suitable electric snare (Fig. 315). The wire loop ensnares the entire pedicle of the tumor and as the wire cuts through its base the loop is gradually drawn up. The wire snare should not cut through the tumor too rapidly, since the object of the electric snare is to destroy as much of the tumor pedicle as is feasible while the wire actually coagulates and destroys it. Additional fulguration of the base if deemed necessary may be done with a blunt tip of the Gorsch suction electrode, assuring complete destruction of the base. The technique requires practice and is not as easy as described.

It is essential that the operator be familiar with his machine and the depth of current penetration, under various settings and in various tissues. A slow cutting current with some coagulation in its wake is the best. Peritoneal penetration is, of course, possible and should this occur, immedi-

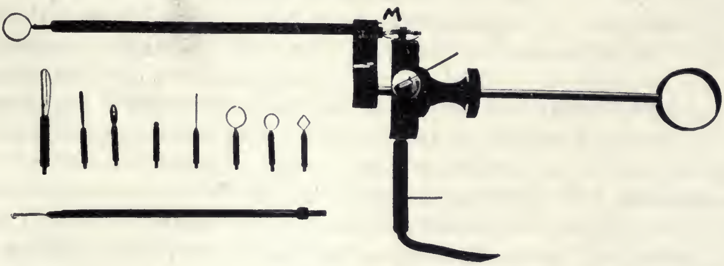

FIG. 315.—Electrosurgical snare particularly useful in proctological electrosurgery, with various types of electrodes. (Gorsch, courtesy of the Am. Jour. Surg.)

ate laparotomy must be done. In carrying out electrosurgical operations about the anus it is advisable to use a separate source of current for illuminating the anoscope or proctoscope because the current from the machine may blow out the illuminating lamps and may likewise shock the patient.

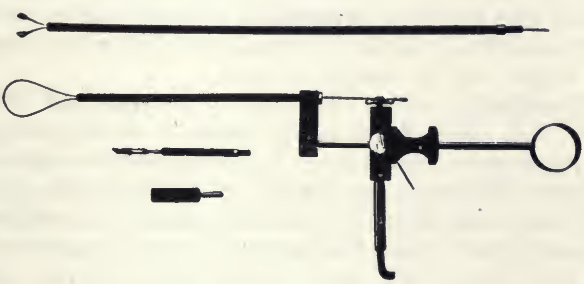

FIG. 316.—Electrosurgical snare showing biopsy cups. (Gorsch, courtesy of the Am. Jour. Surg.)

Frequent re-examination of the site of removal is desirable. New tumors may appear. Radium implants to accessible malignant tumors may also be advisable.

Biopsy.—The cutting current loop affords the ideal method of obtaining specimens of tumors from the rectum or sigmoid and other inaccessible locations. The chances of hemorrhages are greatly minimized and the site of excision may promptly be coagulated to prevent the spread of tumor tissue by implant or traumatic extension.

The author's electrosurgical snare shown in Figure 316 is of particular value in securing biopsy specimens from the sigmoid through long and small caliber sigmoidoscopes.

Proctitis.—Certain types of proctitis with infected anal crypts and glands may be benefited by medical diathermy, as already described. Ultraviolet rays applied through a quartz rod into the rectum may prove of benefit in the chronic cases of proctitis complicated by rectal or anal tuberculosis. Physical measures directed to build up the general condition of the patient are likewise to be considered.

Gonorrheal Proctitis.—Rectal gonorrhea is much more frequently associated with a genital infection of gonorrhea than is usually suspected. Desjardins[1] and his co-workers state that with improved methods of fever therapy 90 to 95 per cent of patients can be cured of this usually so resistant chronic infection. It appears that fever therapy combined with chemotherapy, the sulfonamides, and penicillin will eventually supplant the older and less specific methods of rectal irrigations or topical applications.

It should be worthy of emphasis that rectal gonorrheal cryptitis may be an important focus for protracted gonorrheal arthritis and hence fever therapy should be of particular value in these cases.

Pruritus Ani.—Pruritus ani is sometimes benefited by the application of ultraviolet radiation. A second- or third-degree erythema should be produced, depending on the tolerance of the patient and the condition of the pruritic skin. Experience is needed to determine the correct dosage in the individual. In refractory cases ultraviolet radiation has often proved disappointing.

Favorable results have been reported by Rolfe[6] with ionic medication in the treatment of pruritus ani. Zinc sulphate, zinc permanganate, copper sulphate and iodine have been among the recommended chemicals. Twelve to 20 treatments are usually necessary and the cure is frequently not permanent. The necessity for special apparatus and for an exact technique together with the length of treatments have tended to discourage the average physician from the use of ionization. However, in selected cases the results would seem to warrant its use.

Roentgen radiation in the treatment of pruritus ani should be used cautiously. This form of treatment seems to benefit many cases but recurrence following its application, in the author's experience, has been all too frequent. Roentgen-ray dermatitis or burns with permanent skin destruction have resulted often enough to stamp the roentgen-rays as of at least questionable value. Furthermore, it is impossible to predict the reaction of the perianal skin and mucocutaneous junction in many cases of pruritus ani. In intractable cases Turell[8] has reported some success by tattooing with mercuric sulphide.

Coccygodynia.—In agreement with the statements in Chapter XXVIII the author wishes to go on record that in coccygodynia surgery is frequently disappointing and it should be preferably used only after a thorough trial of diathermy and other physical measures.

Neuralgia, Hysteria of the Rectum, etc.—(Rectal Phobia, Sphincteralgia, Sphincterismus, and Anal Cramp).—This collection of terms refers to a group of ill-defined conditions, usually functional, which manifest themselves primarily through the neuromuscular apparatus of the anorectal region. They are not all well understood, in fact, the innervation of the anus and rectum is not fully understood. These functional aberrations are characterized by sensory disturbances of which attacks of pain, spasm, burning, itching, irritability, etc., are common complaints.

Several of these intractable cases follow rectal surgery in which excessive scarring persists in the anal canal. Reflex possibilities and psychogenic factors are important. It is frequently impossible to assign any causative demonstrable pathology, but organic pathology must be carefully ruled out and psychopathic examinations are advisable.

It would seem that physical measures should be of great value in these intractable cases and this is not sufficiently appreciated. Surgery usually aggravates their conditions. Rectal diathermy, abdomino-rectal, abdomino-vaginal or transpelvic diathermy are most generally available. Cabinet electric baths, ultraviolet radiation, the static wave and the galvanic bath may likewise prove useful. These electrical modalities combine psychic with general systemic effects which may prove of considerable benefit to this type of patient.

Tuberculous Peritonitis, Enteritis and Anorectal Tuberculosis.—The value of the ultraviolet light in the treatment of selected forms of tuberculosis seems well established. It reduces the incidence of pain, cramping, diarrhea, nausea and vomiting, stimulates appetite, and prolongs life. However, the therapeutic value of heliotherapy in this condition depends almost entirely on its general systemic effects and hence local application of light in tuberculosis is of little value. The author prefers large carbon arc lamps.

The proctologist might well avail himself of the value of heliotherapy both before and after operative procedures on patients with tuberculous fistulæ, coccygeal, and sacral tuberculous involvement, and particularly anorectal tuberculous ulcerations which are notoriously resistant to all forms of therapy. Tuberculous involvement of the intestines and peritoneum should be watched for.

A course of general ultraviolet often has a salutary effect on sluggish perineal wounds and in selected cases roentgen-rays may be cautiously used.

Cancer of the Rectum.—Electrocoagulation in the treatment of cancer of the rectum was first introduced by Kolischer in 1910. It was primarily used for cases considered inoperable but with improvements in armamentarium and electrosurgical techniques its scope broadened to include cases also falling within the field of radical surgery. This has provoked some controversial opinions concerning operability and other criteria which are still unsettled.

Earlier diagnosis, improved surgical technique, better pre- and post-operative care together with chemotherapy have increased materially the operability rate and the scope of radical surgery. These factors have tended to circumscribe the indications and limitations of electrosurgical methods and there appears to be less enthusiasm for them than formerly.

Electrocoagulation in rectal cancer has inherent limitations. The more important of these are the location of the tumor with particular reference to adjacent viscera, the extent of the metastases, if any, the configuration of the tumor and finally the grade of the malignancy. The size and location of the primary growth bear no constant relation to the extent of the local or remote metastases or the local infiltration. Obviously electrothermic methods can only destroy the growth accessible through the proctoscope and the depth and ultimate destruction are sometimes difficult to determine.

These limitations are less applicable to radical surgery and they should be carefully considered in the selection of the method to be used.

On the other hand electrocoagulation has three undisputed advantages as enumerated by Sawyer:[7] (1) The almost complete lack of shock. (2) The low morbidity and mortality. (3) The avoidance of colostomy in most cases. These advantages unfortunately apply largely to the inoperable group and they should not receive undue consideration in the rejection of radical surgery.

Electrosurgical methods have definite and justifiable indication in the following cases. The question of operability however is always a moot question which should be based on a careful and complete investigation in competent hands.

1. Inoperable cases—to relieve rectal obstruction and in colostomized patients to relieve hemorrhage and tenesmus.
2. Cases in which radical surgery is contraindicated.
3. Cases refusing radical surgery.
4. Malignant polyps or adenomata.

The commonest indication for electrocoagulation is the malignant polyp or adenoma, usually single, of low grade malignancy and usually readily accessible through the proctoscope. Routine proctoscopy would undoubtedly disclose many of these tumors in their early stages and materially increase the opportunities for their complete eradication by electrocoagulation or desiccation, particularly the pedunculated variety. The location of these tumors with respect to the peritoneal reflection is very important, particularly in the sessilated variety where the unknown factors of local infiltration or extramural metastases must receive serious consideration. The pedunculated tumors are preferably removed with the electric snare (Fig. 280), and the base coagulated as indicated. This procedure offers the maximum of tumor tissue for histological examination.

In the small sessilated tumor it may also be advisable to do a biopsy. With a high grade of malignancy in a young adult patient the decision as to the best approach may be difficult.

Although only a small percentage of malignant growths are amenable to electrosurgical methods a better evaluation and a sharper definition of its indications and limitations is advisable, through a larger number of accurately recorded results.

The technique of electrocoagulation is exacting and requires a thorough knowledge of the electrosurgical modality used and its particular electrosurgical effects on the tissues.

A suction electrode which effectively clears the field of smoke is essential. Proctoscopes should be well lighted from a separate current source than that used for the electrocoagulating unit.

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CHAPTER XXXIII

DERMATOLOGICAL CONDITIONS

General Considerations. Acne Vulgaris. Alopecia. Benign Neoplasm. Callositas. Corns. Dermatophytosis. Eczema Seborrhoicum. Erysipelas. Furunculosis. Impetigo. Keloid. Keratoses. Leukoplakia. Malignant Neoplasms. Neurodermatitis. Psoriasis. Rhinophyma. Sycosis Vulgaris. Telangiectases. Tuberculodermas. Ulcers and Wounds. Verruca. Hypertrichosis. (*a*) Electrolysis. (*b*) High-frequency Epilation.

General Considerations.—Dermatological treatment has been practically revolutionized during the past twenty-five years by the introduction and widespread use of physical therapeutic measures. Foremost among these are roentgen-rays, but included are all other forms of electrotherapy and light therapy, and to a limited extent hypothermy or therapeutic refrigeration, and massage.

Surgical diathermy or electrosurgery is widely employed in the form of desiccation for removal of superficial lesions where good cosmetic results are essential; in recent years it also has been used as an alternate method for the removal of superfluous hair. Warts of all types, keratoses of the seborrheic, senile, radiodermatitic and chemical types are best eradicated with some form of surgical diathermy. Even so-called permanent freckles may be made to disappear when treated with superficial electrodesiccation. Small localized lesions of lupus vulgaris, tuberculosis verrucosa cutis, sarcoid and lupus erythematosus are quickly, easily and permanently destroyed with electrocoagulation or electrodesiccation. Cavernous angiomas, pigmented and hairy moles can be destroyed with little or no scarring by the proper selection and application of electrosurgery. However, in nevi one must be careful not to traumatize a potentially malignant melanoma.

In malignant growths of the skin seasoned surgical judgment is necessary to decide whether electrosurgery is indicated at all and, if so, whether it is to be used alone or in combination with roentgen-ray or radium. Many benign lesions such as fibromas, granuloma pyogenicum, xanthoma, adenoma sebaceum, and multiple benign cystic epitheliomas are often very satisfactorily treated with electrosurgery. Rhinophyma, a most disfiguring condition, can be improved with electrodesiccation, electrocoagulation and electrocutting. The type of current selected depends upon the severity of the condition. Tattoo marks and powder stains may be improved by very superficial electrodesiccation and gentle curettage. The general principles and technique of all electrosurgical methods have been fully described in Chapter XIII. According to Cipollaro, a mistake which often occurs is to remove benign and malignant new growths as well as verrucæ and keratoses with moderately strong electrosurgical currents without using anesthesia. The operator has to work hurriedly and may not remove the lesion thoroughly, because of the great pain caused by electrosurgery. Anesthesia is always recommended.

The galvanic current has been employed for many years in the form of electrolysis as the standard treatment for hypertrichosis, and can be also used for the destruction of telangiectases associated with radiodermatitis, rosacea and nævus araneus. Small nevoid and seborrheic keratoses, multiple benign cystic epitheliomas and adenoma sebaceum as well as small common hairy nevi and the flat, digitate, filiform and small common warts can be destroyed without disfigurement with the galvanic current. There is no danger in treating by this method brown hairy moles that have been present since birth, provided the diagnosis is correctly made. It is difficult sometimes to differentiate a potentially malignant mole from one which is benign. All dermatologists agree that whenever there is doubt one should resort either to radical destructive methods or leave the mole alone and carefully observe it periodically. Iontophoresis has found in recent years an increasing employment in dermatological conditions. Mecholyl iontophoresis is valuable in the treatment of chronic varicose ulcers, lupus pernio, sclerodactylia, scleroderma and Raynaud's disease. Copper iontophoresis has been recommended in the treatment of fungous infections of the skin, especially dermatophytosis and chronic recurrent eczema of the hands. The general technique of iontophoresis as well as of electrolysis has been described in Chapter VIII.

Ultraviolet irradiation, local and general, has a definite applicability in skin conditions, as already stated in Chapter XVIII. There exists some confusion as to the therapeutic effectiveness of light therapy in skin infections; some of this is based on the recently more and more emphasized fact that ultraviolet radiation penetrates only to a very slight depth through the skin (see Fig. 212 of Bachem and Reed); therefore the bactericidal effects of ultraviolet are necessarily limited to conditions which are situated at a depth accessible to this radiation. Scholtz[9] states that bacterial diseases of the skin may be divided into three groups, according to the average depth of the pathological process: Group 1, those wholly or for the most part in the epidermis; Group 2, those wholly or for the most part in the superficial corium; Group 3, those wholly or for the most part in the deep corium or subcutaneous tissue. Scholtz[9] concludes that only a few bacterial diseases are accessible to bactericidal ultraviolet radiation. However, clinical experience shows favorable results in a number of conditions which are situated outside of the effective range of bactericidal radiation. The additional factors accountable for these results appear to be the following: (1) Most of the ultraviolet generators emit a varying amount of infrared radiation which has a definite rôle as an aid in the local defense mechanism; (2) the circulatory changes associated with the erythemal effect of ultraviolet play an undoubted rôle in the subsequent therapeutic effect; (3) compression of the skin with quartz lenses as in the Finsen treatment allows a deeper penetration of the bactericidal radiation itself.

It is evident, that as in all other specialties correct diagnosis is the essential prerequisite for the proper selection of indicated physical measures in dermatology; but in the following alphabetical discussion of the various skin conditions because of limitation of space diagnostic considerations had to be minimal or fully omitted. The treatment of hypertrichosis by electrolysis and by high-frequency removal will be presented separately at the end of this chapter, because of the large amount of detailed technical considerations involved.

Acne Vulgaris.—According to Cipollaro practically all forms of acne vulgaris respond to ultraviolet radiation. Some cases require erythema doses and others do better with more intense radiation. Judgment is required in selecting the particular technique for the particular stage of the disease. Severe cases of acne can be kept under control indefinitely with ultraviolet rays and many of them can be cured permanently. Exfoliating doses of cold quartz are particularly effective in improving post-acne scarring.

Alopecia.—There are two main groups of alopecia, the premature group which may be subdivided into the seborrheic, idiopathic and hereditary types and the areata group which may be of the localized or universal type. All these types have been treated by dermatologists and others with ultraviolet rays. All are not in agreement that this agent is essential in the treatment of these conditions. However, it can be safely stated that it is a useful adjuvant for the treatment of alopecia areata and some cases of alopecia prematura. The doses, however, should be sufficiently large to produce hyperemia or a moderate reaction. It must be understood that in no sense is ultraviolet radiation a "hair grower."

Benign Neoplasms.—*Adenoma sebaceum* consists of small papules which can be destroyed by mild electrodesiccation with perfect cosmetic result. Lesions should be left to slough off naturally and are not to be curetted off.

Fibroma.—Fibroma, especially the small, pedunculated type common on the neck can easily be destroyed by a very light sparking of electrodesiccation. *Xanthoma nodules* also can be removed by desiccation, while in xanthelasma lesions located on the eyelids, destruction by trichloracetic acid usually works better.

Callositas.—Callosities are usually very sensitive and occur for the most part in regions of pressure and friction. They appear most often on the plantar surfaces of the feet. Electrodesiccation is suitable for most of the smaller and medium-sized lesions. In applying the current the author uses no anesthesia during the first treatments. This necessitates staying within the callus to prevent destruction of normal sensitive tissue and causing postoperative pain. Two or three treatments are necessary and at the last, when the tumor is reduced to a small size, a small quantity of novocaine is injected to treat the last vestige of callus. During treatments a protecting pad with an opening the size of the lesion must be worn about the area and continued for about a month to guard against recurrence from too early pressure. Larger calluses can be excised with the cutting current, but this requires full local anesthesia and usually keeps the patient off the feet for a day or two.

Corns.—Corns (clavus) are treated in the same manner as callosities.

Dermatophytosis.—The author[4] has reported a series of chronic cases fully cleared up with 1 to 3 treatments of the thin window lamp, and undoubtedly other ultraviolet generators exert similar beneficial effects. Cipollaro warns that acute cases should not be further traumatized with intensive ultraviolet irradiation. Topical remedies are always used and ultraviolet radiation is a valuable adjuvant in some types. One should not rely solely on ultraviolet rays for the treatment of fungous infections.

Copper iontophoresis is praised by Haggard[3] *et al.* because of the fungicidal properties of copper and its low toxicity. The technique of treatment consists of using rectangular enamel pans for the feet and bain marie basins for the hands, as illustrated. When the infection is on the feet, the hands are immersed in saline solution and the feet in a 0.2 per cent copper sulphate solution; for infection of the hands the relations are reversed. If hands and feet are infected, the solutions in the baths were reversed at the end of the regular twenty minutes of treatment and an additional period of treatment is given. Copper electrodes are used: the positive pole is attached to the electrode in the copper solution and the negative to that in the saline solution. If only one hand or foot is immersed, 4 to 6 milliamperes of current is used, and if both are immersed, 8 to 10 milliamperes of current. In the series reported, these clinicians treated when possible each patient two or three times a week; no other treatment was used. When it was necessary to clean the hands or feet, the crusts were removed mechanically

Fig. 317.—Copper iontophoresis in fungus infection. (Courtesy of F. W. Haggard *et al.* and Jour. Am. Med. Assn.)

with soap and water. However, preliminary soaking of the extremities for a few minutes in a dilute solution of sodium hypochlorite is highly efficacious in preparing the skin for treatment. The treatment was given to 37 patients in whom diagnosis of dermatophytosis was made clinically. Most cases were severe and of long standing. Various types of eruption were present: erythematous, scaly, desquamating, denuded, macerated, fissured, hyperkeratotic, vesicular and pustular. Results were most striking when the infection was particularly active and showed bullæ and vesicles. In most instances, subjective symptoms disappeared within twenty-four hours after the first treatment and the vesicles flattened without rupturing. One of the first results was lessening of the moisture in the skin. When the entire extremity showed dry, normal-appearing skin, treatment was discontinued. Twenty-six patients obtained a clinical cure. The number of treatments required varied from 4 given in two weeks to 18 given in eight weeks, the average being slightly more than 6.

While some dermatologists regard the results of copper iontophoresis as doubtful, it unquestionably represents a method worth trying in all stubborn cases.

Eczema Seborrhoicum.—Occasionally this condition improves when treated with ultraviolet rays, especially if the lesions are chronic and of long standing. To localized areas fairly intensive doses may be administered with the air-cooled lamp. Generalized and recalcitrant cases sometimes respond better after the administration of general body radiation. Chronic eczema of childhood and intertrigo are also sometimes benefited by this mode of therapy.

Fig. 318.—Feet before copper treatment. (Courtesy of N. W. Haggard *et al.* and Jour. Am. Med. Assn.)

Erysipelas.—In recent years the successful use of sulfa drugs has obviated the necessity for much local treatment used heretofore. Mention has been made in Chapter XVIII of the specific effect claimed for ultraviolet radiation on erysipelas. The original investigators recommended local irradiation of the affected area, including $1\frac{1}{2}$ inches of the healthy skin to the extent of a third-degree reaction. Either an air-cooled or a water-cooled lamp may be employed. The area should be left uncovered after treatment. They state that one treatment usually suffices to bring about a critical fall in temperature and a clearing up of the condition and that relapses are rare and can be cleared up with equal promptness on subsequent irradiation.

Furuncles.—In an early stage of a furuncle (incipient abscess or hard boil) an attempt may be made to abort the process by producing a third-degree erythema in the center of the lesion by a local contact ultraviolet irradiation through a suitable applicator. This will take from twenty seconds to a minute according to the condition of the burner. This dosage may be repeated, if necessary, as soon as the skin reaction subsides. Granger recommended either indirect or direct "fulguration" to the center of the boil from the Oudin terminal.

Fig. 319.—Feet after copper treatment. (Courtesy of N. W. Haggard *et al.* and Jour. Am. Med. Assn.)

If the abscess or boil is in the stage of suppuration, repeated exposure to a small luminous heat lamp, one-half hour once, or more often, daily will promptly relieve the unpleasant throbbing and tenderness and promote, like a poultice, spontaneous opening and quick resolution. When the abscess has evacuated or is chronic, exposure to ultraviolet for a second-degree erythema dose, will speed up resolution. It is important that proper drainage be maintained.

Short-wave diathermy has had a passing vogue by some clinicians in recent years on account of the pain-relieving and resorptive effect claimed for it on all types of furuncles.

In multiple abscesses (furunculosis) of adults, a systematic course of general ultraviolet baths should be administered, in addition to local treatment of individual lesions. In infants, similarly, general ultraviolet irradiation is advisable in increasing doses while the feeding is suitably regulated.

Impetigo.—Ultraviolet irradiation, especially of the bactericidal range is indicated; the authors has reported a series of cases completely cleared up by a single ten-minute exposure with the thin window lamp. The additional advantage of this treatment is the avoidance of messy ointments.

Keloids and Hypertrophied Scars.—A keloid denotes idiosyncrasy, and removal by any method that causes traumatism is likely to be followed by a still larger keloid. However, some keloids may be eradicated by first removing them with electrosurgical cutting and while the wound is healing by applying roentgen-rays.

Hypertrophic scars may be due to tension and do not necessarily indicate idiosyncrasy. Larger scars yield only to roentgen-ray or radium, but in smaller ones chlorine-iontophoresis, as described in Chapter VIII brings often a good result if persistently applied.

Fig. 320.—Keloid before treatment with cutting current and roentgen-rays. (Courtesy of Dr. J. J. Eller.)

Fig. 321.—Keloid after treatment with cutting current and roentgen-rays. (Courtesy of Dr. J. J. Eller.)

Keratoses.—Physical measures are sovereign in treating keratoses, but a correct diagnosis and a differentiation of the type in treating of keratosis is essential before the kind and extent of treatment is determined. Keratosis seborrhœica is the most common type and it usually yields promptly to thorough desiccation, which also should include the normal skin around the periphery. According to MacKee and Cipollaro[7] if there is a definite infiltration under the horny layer, the area may be curetted after such desiccation and the resulting wound again electrodesiccated, although such procedure usually leaves a mild permanent scar.

Keratosis senilis is one of the forerunners of epidermoid cancer; it yields to the same treatment as just outlined; in case the lesion is thick or elevated, more thorough destruction is indicated, which should include establishing first a circle of coagulation a few millimeters beyond the lesion and extending down to the corium.

Arsenical keratoses resemble senile keratoses and should be treated the same way. They often give rise to basal or prickle cell cancer and, therefore, if numerous must be treated expectantly and the patient kept under close observation. Roentgen-ray and radium keratoses also yield to electrodesiccation but the outlook is much less favorable because of the frequency of subsequent degeneration and sclerosis.

Leukoplakia may likewise be the forerunner of a cancer; when treated with desiccation the entire thickness of the mucous membrane must be thoroughly destroyed, with the treatment extending beyond the periphery of the lesion.

Malignant Neoplasms.—The diagnosis and treatment of the various forms of cutaneous cancer require adequate skill and experience, and the average physician therefore had better consult in case of all malignancies a colleague who has such specialized knowledge. Basal and squamous cell epitheliomas, melanomas and malignant sarcomas should not be treated with mild destructive agents such as electrolysis, carbon dioxide snow or cauterization, as these usually result in irritation, more rapid growth and widespread metastasis.

Fig. 322

Fig. 323

Fig. 322.—Lymphosarcoma of chin. The lesion was a lemon-size stony hard mass of twelve years' duration in a man, aged sixty years. There was a nut-size hard gland on left side of neck. Microscopic diagnosis of lymphosarcoma. The tumor and gland were removed by the high-frequency knife while the base was electrocoagulated. Following this, three treatments of high-voltage roentgen-rays were given the neck lymphatics and site of tumor.

Fig. 323.—Lymphosarcoma of chin after treatment. No recurrence after two and a half years. (Eller and Fox, New York State Jour. of Medicine.)

Molluscum Contagiosum.—These lesions may be curetted by using a local anesthetic of novocaine or a spray of ethyl chloride; then iodine is applied to the base of each lesion. Very good results are also obtained by electrodesiccation, as in verruca vulgaris.

Neurodermatitis.—Patients with either the localized or the disseminated type of neurodermatitis improve when exposed to ultraviolet radiation. The rays are applied to the entire body. Excessive reaction should be avoided. During the summer, patients are invariably better than in winter. This is true especially in those cases that have the disseminate and generalized variety of neurodermatitis. The same good results may be accomplished during the cold months if generalized ultraviolet rays are applied daily in suberythema doses.

Nevi.—There are a variety of suitable physical agents for the various types of birthmarks.

In Nævus Flammeus or port wine marks occasionally blistering doses of ultraviolet radiation with or without compression from a water-cooled lamp may eradicate very faint lesions or may reduce the color of the more pronounced lesions. Treatments may have to be administered for several months or years. Small-sized lesions may be eradicated by carbon dioxide snow with less scarring than with desiccation.

Fig. 324.—Cavernous angioma before electrocoagulation. (Eller, Phys. Therapeutics.)

Fig. 325.—Cavernous angioma after electrocoagulation. (Eller, Phys. Therapeutics.)

Spider or stellar nevi may be best treated by electrolysis. The advantage of treating dilated blood-vessels by electrochemical cauterization instead of thermal coagulation is that there is a minimal skin destruction and less scarring. With the electrolysis needle, correctly inserted in the lumen of the dilated vein there is an immediate coagulation of its contents and the subsequent shrinking process of the growth leaves an almost invisible scar.

The technique of treatment varies according to whether there is a large central vein or several small ones. A dispersive pad electrode connected to the positive pole is placed under one palm of the patient. The electrolysis needle connected to the negative pole of the galvanic source is inserted for a short distance into the central vein and a current of $\frac{1}{2}$ to 1 milliampere passed for not over one minute. The blood-vessels treated should change almost immediately to a whitish streak. Small capillary veins and angiomata may be treated by repeated transfixation through the entire mass as in moles. If there are several small visible blood-vessels they should be treated individually, but the insertions are best spaced as far apart as possible to avoid confluence of the secondary reaction and a visibly depressed scar.

Pigmented Nevi.—The common mole, a smooth elevated lesion of normal color or of various shades of brown can be removed by electrolysis without any scarring. If brown, pigmented with hairs, these must be first destroyed by electrolysis, afterwards the lesion often disappears without further treatment or the remnants can be desiccated. Black pigmented moles without hair are almost always a dormant melanotic cancer and should be left untreated unless there is an area which is subject to irritation or where there is some sign of growth. The removal should always be done radically for any mild palliative treatment may result in a general metastasis and death.

Pityriasis Rosea.—The course of this disease can be considerably shortened by the use of ultraviolet radiation. Not only do lesions disappear but new lesions fail to appear. According to Cipollaro "cold quartz" seems to yield better results than "hot quartz" in most cases. This is probably due to the exfoliating properties of these shorter wave length ultraviolet rays.

Psoriasis.—Carefully applied ultraviolet radiation in suberythema doses is valuable in the treatment of this disease. However, doses sufficiently large to cause erythema may also cause widespread dissemination and generalization of the disease. A special technique has been developed by Goeckerman and modified by O'Leary[8] in employing coal tar as a sensitizer to ultraviolet radiation. A 3 per cent coal tar ointment is applied thickly overnight over all patches of psoriasis, removed next day by a light weight mineral oil, being careful to leave a thin film of the oil on the skin. At the first treatment radiation is applied for one minute at a 30-inch distance after dividing the skin surface into six areas. The time of exposure is increased and the distance decreased each day in order to maintain the skin in a state of mild erythema.

After irradiation the patient spends half an hour to two hours in an oatmeal bath or in a tub of water kept at approximately 95° F. This procedure loosens the scales and allows the patient to remove them by brisk rubbing of the skin while in the tub. After the bath a thick coating of the ointment is applied again to the lesions. An inexpensive cotton suit of underwear or a gauze covering is worn to protect the bed clothing. In addition, O'Leary uses autohemotherapy. The technique consists of drawing 10 cc. of blood from the cubital vein and injecting immediately 5 cc. into each buttock. This is administered at two-day intervals for five doses.

FIG. 326.—Rhinophyma before treatment. (Courtesy of Dr. J. J. Eller.)

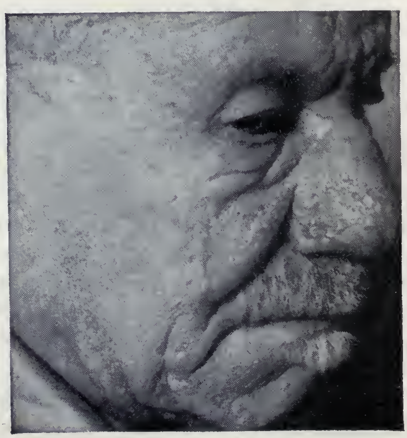

FIG. 327.—Rhinophyma after combined electrosurgery and roentgen-ray.

Rhinophyma.—According to Eller the early cases can readily be cured by electrocoagulation. They are treated by penetrating each nodule or enlarged sebaceous gland with the needle. The current is then turned on for the time necessary for coagulation. After several treatments there is a slight contraction of the inflamed and enlarged sebaceous glands, with the result that the size of the nose gradually returns to normal. At this stage, fractional roentgen-rays, unfiltered, are given weekly for several doses in order to prevent a recurrence of the enlargement of the glands. In the more advanced cases, surgery must be resorted to, followed by roentgen-ray therapy.

Sycosis Vulgaris.—Chronic pustular folliculitis of the bearded region is often incurable. However, patients are much better in the summertime when they are exposed to solar radiation than they are in the winter. Localized as well as generalized ultraviolet irradiation combined with topical remedies often improves this condition.

Telangiectases.—Telangiectatic vessels which occur without discernible cause and those found in radiodermatitis and rosacea may be made to disappear when treated with intensive water-cooled ultraviolet rays under compression. One should avoid overirradiating tissues which have been damaged by roentgen-rays. Congenital stellar nevi should be treated as described under that heading.

Tuberculodermas.—Most of the skin manifestations of tuberculosis are aided in varying degrees by exposure to ultraviolet rays. According to Cipollaro the tuberculodermas most frequently treated with light are erythema induratum of Bazin, lupus vulgaris, scrofuloderma and tuberculosis cutis orificialis.

A. Erythema Induratum of Bazin.—General as well as local ultraviolet radiation, combined with bed rest, high-vitamin and salt-poor diet and injections of tuberculin yield satisfactory results within a few weeks.

B. Lupus Vulgaris.—The results of treating this disease with ultraviolet marked the beginning of the era of artificial ultraviolet radiation. It is well to supplement local radiation with general radiation, especially if there is no evidence of acute visceral tuberculosis. Best results are obtained with the Finsen lamp (see Chapter XVIII). Perseverance in the administration of other sources of ultraviolet rays is essential for successful results.

C. Scrofuloderma.—Local and general ultraviolet radiation should be used in combination with systemic treatment. Gerson-Sauerbruch diet and tuberculin injections are valuable adjuvants. Small and often repeated doses of ultraviolet rays (natural or artificial) are better than large doses applied infrequently.

D. Tuberculosis Cutis Orificialis.—This form of cutaneous tuberculosis often yields to treatment with ultraviolet radiation, but unfortunately since it is a manifestation of an extension of visceral tuberculosis, in spite of improvement in the local lesions the outcome is usually fatal.

Verruca Vulgaris.—The ordinary types of verruca are readily destroyed by electrodesiccation and then removed with the curette. If a small spark is used very little scarring results. A local anesthetic, such as novocaine solution, is used.

In destroying warts with desiccation one should guard against blistering the surrounding normal tissue. The keratotic areas of the wart are such poor conductors of current that the current often shunts off the wart to the adjacent normal skin where it is concentrated sufficiently to blister. This may be prevented by inserting the needle through the wart to the soft moist base which is a good electrical conductor. Here the current generates heat which destroys the growing center. It is usually preferable to cut the top of the desiccated wart off with scissors and redesiccate the base to prevent recurrences.

Ulcers and Wounds.—Among the many varieties of ulcers, varicose, trophic and syphilitic ulcers are the most frequently seen by the physical therapist. Whether an ulcer is primarily due to a specific organism or to trauma, secondary infection with pyogenic organisms is always present. Physical measures aid in clearing up this sepsis, in stimulating regeneration of epithelium and, in chronic ulcers, in improving defective circulation and poor nutrition.

Ultraviolet irradiation from either an air-cooled or water-cooled source is a generally used measure. The surface of the ulcer must be carefully cleansed from discharges and all traces of ointments. A second-degree erythema dose is applied in the average case either from an air-cooled or water-cooled lamp. Preliminary radiation for from fifteen to thirty minutes from a heat lamp is advisable. The ulcer is then covered over with a mild antiseptic ointment, preferably boric acid ointment, and the treatment is repeated two to three times at two to three-day intervals, according to the condition. When the ulcer looks cleaner and new granulations appear, only first-degree erythemal or suberythemal irradiation should be employed preceded by one-half hour of luminous heat radiation at a distance of comfortable warmth.

Fig. 328.—Treatment of varicose ulcer by mecholyl ion transfer.

In tuberculous ulcers a course of general irradiation is indicated in conjunction with the local treatment. In trophic ulcers such a course is frequently also of benefit.

In chronic leg ulcers where the circulation is poor, longitudinal diathermy may be instituted, applied with a foot plate and a cuff below the knee and a mild dosage for thirty minutes. The hot whirlpool bath is even more effective on account of its additional cleansing and stimulating action. It may be applied at a temperature of 105° to 110° F. for half an hour and followed by ultraviolet irradiation.

The galvanic current is a valuable alternate measure in particularly resistant cases, in the form of copper or mecholyl ionization. Copper ionization is administered with the following technique: All interstices of the ulcerated surface or sinus are packed with small pledgets of cotton soaked in a 1 per cent solution of copper sulphate. A suitable metal plate is placed on top of this layer and is held in position with a rubber bandage. Treatment is applied for ten to twenty minutes at a suitable strength of current according to the condition. For an ulcer of a silver-dollar size from 3 to 5 milliamperes of current may be employed for ten to fifteen minutes; this treatment is repeated once or twice within a few days according to the change in the appearance of the ulcer.

In *varicose ulcers* excellent results were reported with mecholyl ionization (J. Kovács[4]). The technique consists in wrapping around the foot and leg reinforced asbestos paper saturated with 0.5 per cent solution of mecholyl and connecting this to the positive pole. A dispersive pad is connected to the negative pole. The ulcerated area is not covered during treatment until a firm scab has formed over it. Twenty to 30 milliamperes of current are used from twenty to thirty minutes and treatment generally given two or three times weekly. Simple varicose ulcers heal more rapidly than other indolent ulcers which have a foundation in thrombophlebitis, obesity, trauma or arteriosclerosis.

In chronic leg ulcers other supportive measures are important, especially for the prevention of recurrence. Varicose veins should be treated by elastic bandages. In many cases weekly applications of Unna's paste boot or elastic adhesive bandage are very effective. If there are no contraindications the veins may be obliterated by injections or ligation.

Leg ulcers due to arterial disease may be helped by mechanical intermittent occlusion and use of radiant heat.

Infected wounds respond to ultraviolet irradiation applied with the same technique as for ulcers. Preliminary exposure for one-half hour to luminous heat or infrared is even more important. As a matter of fact many of these wounds improve rapidly on heat radiation alone, applied daily for thirty minutes or longer, at a distance of gentle warmth. The classical observations of Bernhard of Switzerland on the action of sunlight on infected wounds and those of the late Ochsner of Chicago on the effects of luminous heat on operative and other wounds served as the foundation for the present-day widespread employment of light therapy in these conditions.

HYPERTRICHOSIS

Removal of superfluous hair or epilation by physical means has become nowadays a procedure very much in demand for cosmetic or other reasons. Roentgen-ray application which was formerly advocated for a period has been totally abandoned because of its inherent dangers: the dose destructive for the hair root must be applied through the entire thickness of the skin and is, therefore, often followed by atrophy and telangiectasis, with more disfigurement than originally.

The two methods of present-day efficient and safe hair removal are electrolysis or removal by electrochemical destruction, and high-frequency removal, preferably by electrodesiccation. Both methods bring the required intensity of caustic application just where it is wanted and are followed by practically invisible scarring. Both methods require a definite amount of skill, knowledge of anatomy of the skin, of antisepsis and of tissue tolerance to thermal and chemical trauma, as well as of the physics and mechanics of the apparatus involved. Electrolysis is the older and more widely practiced method and has been much exploited by lay operators. Physicians should be able to acquire without much difficulty the necessary skill and experience to do either form of procedure.

Epilation by Electrolysis.—The essential part of the procedure is to introduce a fine needle, connected to the negative pole of a galvanic generator, to each individual hair follicle and employ an amount of current just sufficient for destruction.

Equipment.—1. A source of galvanic current, as described in Chapter VIII.

2. Active electrodes, fine needles for introduction into the hair follicle. There are two types of needles, non-insulated and insulated. (Fig. 329).

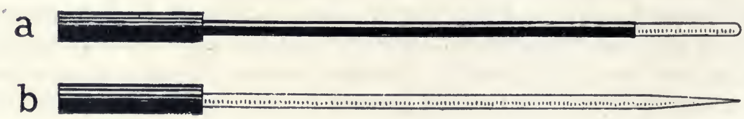

FIG. 329.—Electrolysis needles. *a*, insulated; *b*, non-insulated. (Courtesy of Dr. M. H Marton and Medical Record.)

The more commonly employed non-insulated needles are made of steel or iridoplatinum. They end in a sharp point which facilitates entry into the hair follicle. Non-insulated needles are held in a needle holder (Fig. 330) which is usually furnished with a current interrupter. In the present-day technique the interrupter is seldom used.

FIG. 330.—Needle holder with interrupter and needle.

Insulated needles are made of fine wire with a round end; almost the entire length of the wire with the exception of about 1 millimeter at the end is insulated by several layers of enamel and this arrangement provides for the concentration of the current on the end of the needle. The needles are held in a small base which is directly connected with the fine cord leading to the negative terminal of the generator. These needles are especially useful for the so-called multiple method of hair removal.

3. Accessories: (*a*) Dispersive electrode, connected to the positive pole; either a moist pad, at least 2 by 3 inches in size, placed under the palm of the patient's hand or a sponge moistened with salt solution and held by the patient, or a cylindrical metal electrode held in the palm of the patient. (*b*) Conducting cords as light as possible; a heavy cord drags on the needle holder and makes manipulation clumsy. (*c*) A fine epilation forceps (tweezers) for the lifting out of the hair after its follicle has been destroyed.

The forceps with little spring will tire the operator's fingers less. Some needle holders carry an enlarging glass; this is often awkward on account of its fixed position; eye-glasses with suitably strong lenses or a hand lens are better. (*d*) Good light from an artificial source with a reflector on a flexible stand is indispensable. The author uses with great satisfaction a special light equipped with an adjustable magnifying glass (Fig. 331).

Fig. 331.—Magnifying lamp suitable for epilation and other operations requiring bright illumination.

Preparation of Electrolysis.—The patient's skin is sponged with alcohol; this also removes the skin grease. The operator's hands are washed with soap and water and the needle is sterilized in alcohol or by dry heat. Electrolysis is a tedious procedure and both the patient and the operator should be as relaxed as possible during the proceedings. The light should be so placed that its glare does not disturb the operator and the patient's eyes should also be shielded. The patient should be placed on a table and the operator should be comfortably seated with the forearm supported. Some operators place the patient in a reclining chair and sit behind them; the chair is so adjusted that the head-rest and the patient's head are almost in the operator's lap.

The current control of the galvanic generator should be within easy reach of the operator so that current strength can be immediately adjusted according to the sensitivity of the parts and the condition of individual hair follicles. A watch with a plainly visible second hand should also be placed so that the operator can easily time the seconds.

In the technique of operation there is a choice of two procedures. With non-insulated needles, the flow of minimum current is set before the insertion of the needle and the current is kept "on" during the entire performance. With the insulated needles, the current flow is started only after the needle or a group of needles has been inserted into the hair follicles. The second procedure is somewhat safer so far as subsequent scarring is concerned. The method with non-insulated needles is generally employed and will be described first.

Setting of Current Flow.—Preliminary setting of the current flow at a minimum strength speeds up the operation and also helps the needle to slip in much easier in each follicle, as the softening action of the negative pole takes effect as soon as the needle touches the follicular opening. With this arrangement the length of the current flow is simply controlled by the insertion and withdrawal of the needle; the current strength may be changed at any time according to circumstances.

The preliminary setting of the rheostat should be done by placing the patient's palm on the dispersing electrode and touching the back of the hand with the needle, without inserting it in a hair follicle; this also gets the patient used to the sensation of the current. A rheostat setting allowing the flow of $\frac{1}{2}$ milliampere under the condition described usually furnishes a satisfactory strength, about 1 milliampere of current flow for the operation.

The Operation.—The patient should be assured that except for a slight stinging at the point treated, there will be no sensation of "shock" which the timid seem to expect. Patients must be instructed to keep the palm pressed firmly against the dispersive electrode during the entire course of the operation.

The operator grasps the needle holder, connected to the negative pole, with one hand and exerts slight traction with the free hand on the parts to be treated. Observing the direction of the axis of the first hair selected, he inserts the needle gently alongside the hair, without any pressure. Traction helps to dilate the follicular opening and straightens the hair follicle. If the direction of the needle is correct it will slip in without difficulty, and an operator with some experience will have no difficulty in judging by a sense of touch when the end of the hair canal has been reached. This depth varies from $\frac{1}{16}$ to $\frac{3}{16}$ inch, according to the type of hair and its location.

With the needle correctly connected and entered, a white foam will appear in the opening of the hair follicle very soon and a fine crackling noise may be perceived; both of these are due to hydrogen bubbles produced by the negative pole. The operator should ascertain the strength of current flowing, by glancing at the milliammeter; the time and current strength necessary for the destruction of the hair papilla vary according to the coarseness of the hair. With a hair of average thickness, a current flow of 1 milliampere for thirty to forty seconds is sufficient; for coarse hairs the strength of current should be $1\frac{1}{4}$ to $1\frac{1}{2}$ milliamperes, with finer hairs only $\frac{1}{2}$ milliampere and on the lips only $\frac{1}{4}$ milliampere for the same length of time.

At the end of this period the needle is withdrawn and the hair treated is grasped by the forceps held in the free hand. It should be possible to lift it out from the follicle with hardly any pull. The end of a correctly removed hair shaft should show the thick hair bulb at its lower end, and there are usually a few hydrogen bubbles clinging to the shaft.

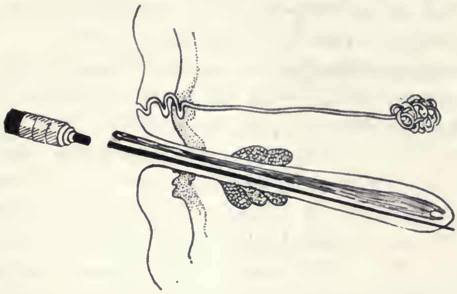

FIG. 332.—Removal of superfluous hair: Epilation needle is correctly inserted along the hair shaft.

If resistance is encountered in removing the hair, no force should be employed in pulling it out; either the needle may have been inserted in the wrong direction or not enough current was used. Hair follicles, as a rule, run at an oblique angle from the skin and, therefore, the needle must be inserted at a corresponding angle and be felt sliding in easily in the direction of the hair shaft. Any hair which does not come out easily after the first treatment may be attacked again immediately by reinserting the needle in the correct direction and by assisting with gentle traction of the skin to straighten out a possibly tortuous hair follicle. In other cases, adding a few seconds to the flow of current or increasing its strength by 0.5 milliampere will help, according to the judgment of the operator.

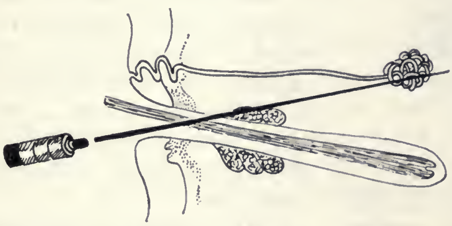

FIG. 333.—Epilation needle is inserted at the wrong angle, forcing a false passage. As a result the papilla of the hair will not be destroyed and the hair will grow out again.

With a current more than 1 milliampere there may be danger in the hands of beginners of using it too long and causing subsequent "pitting" of the follicle due to scar formation, hence the technique of some operators of trying every few seconds to remove the hair by gentle traction of the forceps, while the needle is still inserted and withdrawing the needle as soon as the hair comes out.

In the average case of hypertrichosis the experienced operator will have little difficulty in continuing after removal of the first few hairs with the current strength found effective and comfortably tolerable. One should be careful in not removing at one sitting too many closely adjacent hairs, for this may result in too much irritation afterward. One also should avoid areas that show signs of previous irritation. After a few hairs in the same location are removed, the sensation of the patient at each insertion of the needle usually becomes less, either due to a certain anesthetizing influence of the current or perhaps simply to the patient's getting used to the procedure. In a sitting lasting from one-half to one hour, 25 to 50 hairs can be removed, depending upon the individual case, the coarseness, proximity and direction of the hair follicles.

Technique With Insulated Needles.—Insulated needles offer the advantage that the current flow is restricted to a small area at the end of the electrode, once it has been properly inserted into the follicle. (Fig. 334.) This advantage would be lost if the needle were inserted with the current "on," hence the necessity of starting and shutting off the current flow for each hair and the development of the "multiple" electrode method to avoid the inevitable loss of time with individual hairs.

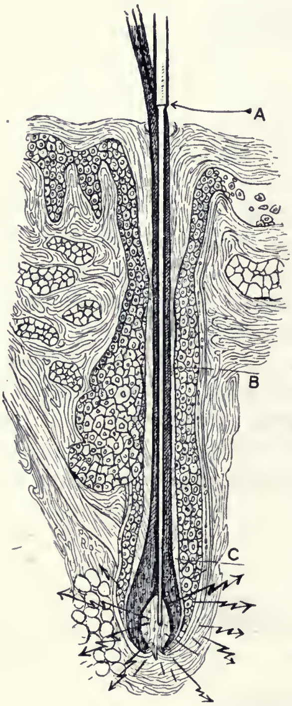

FIG. 334.—Schematic diagram of insulated electrode in hair follicle (*A*). *B*, inactive insulated portion; *C*, active insulated portion. (Courtesy of Dr. M. H. Marton and Medical Record.)

Insulated electrodes and their holders are much lighter than the non-insulated; they cannot be forced into the hair follicle and the needle will bend rather than enter a follicle at a wrong angle. These electrodes must be held about 1 inch back of their tip between the thumb and index finger of the operator and inserted with a slight rotating motion into the hair follicle, observing the direction of the hair. Once properly inserted the electrode usually easily slips along the hair and there is no danger of its piercing the bottom of the follicle. After the needle is inserted the current is gently started, turning on the rheostat to 2 milliamperes, which is kept up from fifteen to twenty seconds; with a strength of only 1 milliampere, the flow must be kept up twice as long. After this period the current is turned off, the electrode withdrawn and the hair lifted out.

With insulated electrodes there is more difficulty in entering hair follicles; this is frequently due to the clogging of the follicle by skin fat and may be remedied by wiping the part off repeatedly with alcohol or softening it with a little cold cream. At times it may be necessary to resort to a non-insulated electrode.

In the multiple electrode method from 4 to 6 electrodes held in a suitable holder placed on the patient's head are inserted. Their cords are united and their common terminal is inserted in the negative terminal of the generator, the dispersive electrode is connected to the positive terminal. Current strength and time of flow must be calculated according to the number of needles inserted. With skilled operators doing a large amount of electrolysis this method results in saving of time as, once the needles are inserted, all hair roots are simultaneously destroyed.

Test Treatment.—For beginners in electrolysis and in case of delicate skins or location it may be advisable to remove at the first sitting only a few hairs with a minimum of current strength (not more than 1 milliampere), and in inspecting the area at five-day intervals. Test treatment enables the operator to discover special sensitivity and gets the patient more easily accustomed to the full treatment; it also demonstrates the healing qualities of a particular skin. Except in unusual instances, electrolysis should not be so painful that patients hesitate in going on with it; the great majority do not complain about pain at all. It is not a good plan to use the same strength of current in every patient.

Complications and Dangers.—The chief danger with an unskilled operation is a false passage by forcing the needle through the side of the follicle, as shown in Figure 333. In the hands of careless operators there also exists the danger of tattooing the patient if the steel needle is connected to the positive pole instead of the negative one; the polarity effect of the current will lead to the deposition of iron oxide around the opening of the hair follicle. Very occasionally there may be some capillary bleeding from one follicle; this signifies that the needle has gone outside or below the follicle; for the follicle itself will never bleed because it is outside of the skin. At times a sudden edema or blanching may appear around the needle without any hydrogen bubbles; this also shows that the needle penetrated through the follicle. The cautious operator will soon automatically acquire the proper sense of touch and never force the entry of a needle.

Postoperative Treatment.—After treatment the parts should be sponged off with alcohol and a mild antiseptic dusting powder or a soothing lotion applied. The employment of alternate hot and cold compresses at intervals of every hour or so for the first twenty-four hours is often helpful in keeping down the inevitable skin reaction to a minimum. In other cases frequent dabbing with a mild "lotio alba" solution is advisable.

A slight swelling around each follicle treated and a certain amount of diffuse redness over the entire area is inevitable in every case as an immediate sequence of a mild chemical and mechanical irritation. Twenty-four hours later a red ring as after a bee sting may be seen around each hair follicle treated, and this may remain for several days. Over some of the follicles a soft scaly scab forms which falls off in a few days, leaving a scar which should be invisible except on very close inspection. If hairs too close together are removed, these scars may become confluent and remain unsightly for some time.

Number and Frequency of Treatments.—An interval of five to seven days is advisable before repeating treatment in the same area. If a patient is anxious to have treatment continued as rapidly as possible, one can work in a different area of the skin every few days.

The number of treatments necessary to remove all hairs will depend on their total number, their closeness to each other and their degree of attachment to the papilla. A few scattered coarse hairs are usually definitely removed in one sitting. When there is considerable amount of work to be done, one should begin working for a shorter period at first and extend the time gradually, repeating the treatment as frequently as practicable.

From 10 to 20 per cent of the hairs removed may show return, but can be removed permanently at follow-up sittings. Poorest results are to be expected in patients with an abundance of fine downy hair; these patients must agree from the beginning to submit to a much prolonged course of treatment.

Follow-up treatment for removal of the percentage of unsuccessfully treated hair follicles should begin about three weeks after the last treatment. One reason for missing some of the hairs at first is the fact that many women come for treatment with closely shaven or clipped hairs. They must be instructed to come for follow-up treatments with the newly grown hair left untouched.

There is no guarantee that after a series of treatments no other coarse hairs will form in a certain area. Likewise there is no evidence that removal in any way stimulates the formation of new hair. Later outcroppings can always be easily controlled.

Epilation by High-frequency Current.—This procedure has been gaining increasing favor in recent years. Its use demands an apparatus furnishing a very fine desiccating current under perfect control. Like in electrolysis the procedure consists in the destruction of the hair follicle by the insertion of a fine steel needle and by turning on a very minimum of current for a length of time estimated according to the size and location of the hair.

Placing and *preparation* of the patient should be done as in electrolysis. Besides a necessary apparatus, the required accessories are a fine needle in a suitable holder, a foot switch and a pair of spring forceps and, of course, good natural light or artificial light with an adjustable reflector and for operators of poor eyesight some special magnifying device.

While long-wave spark-gap apparatus is the most convenient, it is also possible to employ any short-wave diathermy apparatus provided that it is equipped with an extra resistance coil to cut down the output to a very small amount; because of the necessity for a biterminal technique (short-wave apparatus does not furnish a desiccating current) besides the usual active needle electrode a second dispersive electrode has to be employed; this has to be placed near the patient at a distance determined by the conditions in the particular circuit. Such a set-up is somewhat cumbersome compared to the simplicity of using the spark-gap machine.

The Operation.—The essential procedure is the sliding in of the needle tip without any force. Beginners should start with gross hair; if it is too long and interferes with the introduction of the needle it can be clipped. Most hairs stick out at a slight angle to the skin surface and the operator should insert the needle parallel to the hair shaft. With a little practice under adequate light this can be easily learned by persons with good eyesight and a steady hand. In some cases seizure of the hair with the forceps will help to guide the needle into the follicular opening. The depth of insertion should be to the point where the needle meets with slight resistance. Patients usually do not mind the insertion of the needle at all.

As soon as the needle electrode is in proper position, the current flow should be started by light pressure on the foot switch; it should be kept up for only the count of one—the space of a second. It is important that the foot of the operator should be comfortably placed, though only a slight pressure of the big toe or the ball of the foot is needed. The patient should be told that only a slight sting will be felt when the current flows. After the first second, the foot should be taken off the switch and immediately depressed again, repeating again the procedure at the count of two, three, four up to eight to ten seconds, or more often, depending on the coarseness of the hair.

At the close of the treatment period with skilful technique there is hardly any change except slight blanching and the hair can be lifted out easily from the follicle, with its root plainly showing. There is very little pain in the average patient, for the gentle current itself brings about anesthesia around the follicle. Definite pain and slight sparking around the needle tip will make the patient twitch, however, if an absent-minded operator keeps his foot on the switch while inserting or withdrawing the needle.

Small thin hairs may need only three to four seconds for complete removal; if in coarser hairs, or hairs with an irregular root, gentle pulling with the forceps does not bring out the hair easily, it is advisable to reinsert the needle and add a few seconds to the treatment time. Never use force to pull out a hair.

In proceeding with the operation, just like in electrolysis, care must be taken not to take out too many closely grouped hairs in order to keep postoperative reaction at a minimum. Occurrence of capillary bleeding is a sign that the follicle has been punctured at one place. It usually stops on very slight pressure and has no after-effect.

In contrast to the normal, more pronounced, inflammatory reaction and scab formation around each hair follicle treated by electrochemical destruction and occasional infection and swelling of one or more follicles, with skilled high-frequency destruction there occurs, as a rule, only slight reddening around each follicle and the formation of only a minimal scab. Patients should be warned to let scabs separate voluntarily, as the cosmetic result is better.

In the author's experience high-frequency epilation is much speedier, less painful and causes much less reaction than electrolysis and may be used as a method of preference by skilled operators. From 100 to 150 hairs can be comfortably removed during an hour's treatment, compared to an average of 50 with electrolysis. However, because of the rapidity of the procedure, the percentage of recurrence is usually greater.

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CHAPTER XXXIV

DISEASES OF THE EAR, NOSE AND THROAT

By WALLACE MORRISON, M.D.

PROFESSOR OF OTOLARYNGOLOGY, POLYCLINIC MEDICAL SCHOOL AND HOSPITAL, NEW YORK

Furunculosis of the External Canal. Acute Non-suppurative Otitis Media. Acute Suppurative Otitis Media and Mastoiditis. Chronic Suppurative Otitis Media. Chronic Catarrhal Otitis Media. Otosclerosis and Auditory Nerve Deafness. Acute Rhinitus. Chronic Generalized Hypertrophic Rhinitis and Chronic Atrophic Rhinitis. Vasomotor Rhinitis and Hay Fever. Acute Sinusitis. Acute Pharyngitis. Chronic Pharyngitis. Hypertrophied and Infected Lymphoid Tissue. Acute Tonsillitis. Electrosurgical Removal of Tonsils. Acute Laryngitis. Chronic Laryngitis. Laryngeal Tuberculosis.

General Considerations.—Electrotherapy is coming more and more into its own in the field of oto-rhino-laryngology. In many conditions in this region electrotherapy offers methods of treatment which are indispensable; the bloodless removal of hypertrophied or diseased tissue or of accessible new growths by electrosurgery is an example. In other conditions electrotherapy offers relief of symptoms in ways which are not equalled by other methods of treatment; relief of pain by application of luminous heat or infrared radiation in very many of the acute inflammatory processes in the ear, sinuses and pharynx is an example. In still other diseases it offers methods which readily take the place of older forms of treatment; zinc ionization in chronic otitis media is an example. In other conditions it affords treatment which must be used only in conjunction with the accepted forms of medical and surgical treatment; medical diathermy for acute sinus infection must not be given without obtaining the best possible drainage of the sinus affected by the usual intranasal medication, suction, etc., and medical diathermy in tinnitus and deafness must always be accompanied by removal of causative factors, proper local and general treatment, if good results are to be achieved.

The *modalities* used are: (*a*) Luminous heat; (*b*) infrared radiation; (*c*) ultraviolet radiation; (*d*) galvanism and ion transfer; (*e*) diathermy, medical and surgical; (*f*) short-wave diathermy.

DISEASES OF THE EAR

The Pinna and External Auditory Canal.—Acute Dermatitis of the Pinna and External Canal.—This condition may be treated by application of luminous heat in mild doses, once or twice daily, avoiding sufficient heat to irritate the inflamed skin; the luminous heat may be followed once daily or every other day by a short irradiation of the ultraviolet light, giving only a fraction of a first-degree erythema dose. Cold, wet dressings of aluminum acetate solution or tampons of boroglyceride between treatments are very helpful.

Subacute and Chronic Dermatitis of the Pinna and External Canal.—This condition may be treated much more vigorously, purposely giving stimulation. The best results are obtained by blistering doses of the water-cooled mercury vapor ultraviolet lamp at short distances, with or without the quartz rod applicator. Not too large an area should be blistered at a time; treatments to any one area should only be repeated when the reaction of the previous dose has subsided.

Furunculosis of the External Canal.—Furunculosis may be treated in the earliest stages of the process with the water-cooled ultraviolet lamp, with or without the quartz rod applicator. A dose is given sufficient to cause a contact dermatitis without blistering, over the affected part, and a small zone of normal skin about it. This often aborts suppuration.

Short-wave diathermy to the ear is very useful in relieving pain, and at times in preventing suppuration. It is most readily applied by seating the patient in a comfortable wooden chair, between the arm brackets of a suitable floor stand. To one arm of the stand, a 4-inch circular, spaced condenser plate is attached. It is applied to the affected ear, after being covered with sterile paper; or a layer of Turkish towel or a $\frac{1}{2}$-inch thick felt pad may be inserted between the ear and the electrode. The plate must be held gently but firmly against the head so that the pinna is flattened against the side of the cranium. A 6-inch circular spaced condenser plate is attached to the second arm of the stand and placed 2 inches away from the opposite side of the head, or it may be covered with a $\frac{1}{2}$ inch of felt and placed against the opposite shoulder. The points of technique enumerated in Chapter XI must be observed and accordingly one must be sure that metal objects such as wire hair pins, earrings, metal spectacle frames, metal necklaces, etc., are removed from the area beneath the plates. If the electrode is not placed so as to compress the pinna against the head its protruding margin will become uncomfortably hot, or may be burned. The careless placing of either electrode over a prominent bony area will lead to focal heating and a burn may result.

After the current is turned on the controls of the machine are adjusted until the patient feels a gentle and comfortable heat beneath the small electrode. He is allowed to control the current with a foot switch, and is instructed to release the switch instantly if he feels any uncomfortable sensation, or wishes to change his position. A trained attendant must be within instant call at all times. Felt pads and towel or paper spacers placed between electrode and skin must always be dry, and so attached to the electrode that they cannot become displaced. The treatment is given for fifteen minutes and may be repeated twice daily.

The tolerance of the patient is the only guide to the amount of current to be used for there is no way of accurately measuring the amount of current flowing through the patient in the high-frequency field. The controls must always be set low at first and very gradually increased.

Luminous heat is a simple and often quite effective means of relieving the pain of furunculosis. It may be applied for twenty minutes every hour or two hours, with the lamp so placed that the ear becomes comfortably warm. Wet dressings of aluminum acetate solution or tampons of boroglyceride containing 4 per cent salicylic acid between treatments are indicated. When suppuration with pointing has occurred the furuncle may be incised with the cutting current without hemorrhage.

The Middle Ear and Mastoid Process.—Acute Non-suppurative Otitis Media.—This condition is very much benefited by luminous heat or infra-red radiation applied to the entire side of the head, for twenty minutes every hour or two hours. Pain is relieved, and the outpouring of serum in the middle-ear may be prevented. When inflation of the middle-ear shows the presence of serum after the early stages, and particularly in the subacute cases, daily treatment by medical diathermy is advisable. It should be applied with metal electrodes placed within the external canals of both sides. The current is passed for fifteen minutes and always kept within the limit of toleration.

The use of short-wave diathermy is even more efficacious and easier of application. It is applied as has been described for furunculosis, above. The treatment is given for fifteen minutes twice daily. A very mild degree of heat will usually relieve pain and promote absorption of serum.

Acute Suppurative Otitis Media and Mastoiditis.—Here surgical treatment plays the most important part by far; the absolute necessity for prompt incision of the drum and of well-timed exenteration of diseased mastoid cells is no longer open to question. Luminous heat may well be used for a short period in an endeavor to abort suppuration in the tympanum; persistent pain and rising temperature call for incision of the drum without any further waiting. Once free drainage has thus been established, the use of luminous heat is very valuable in relieving pain, promoting drainage and perhaps in preventing spread of the infection to the mastoid cells. Infrared radiation may be used as an alternative, especially in children made restless by the luminous heat. The general resistance may be increased by full-body ultraviolet baths in increasing doses daily. Even when an acute mastoiditis is present, in the absence of signs of complications, the above régime may be followed for a time with the hope that the process may resolve. The length of trial must vary with the individual case, and surgery must no longer be withheld when it is evident that the process in the mastoid is not resolving.

Short-wave diathermy may be tried in place of the luminous heat or infrared radiation. It is useful for the relief of pain and the promotion of healing through the hyperemia brought about by its deep heating effect. It is applied as described under furunculosis above, using a gentle heat over the affected ear and mastoid; it must not be continued if it increases pain and fever. It should not be carried on when it is obvious that the suppuration in the mastoid process is not resolving.

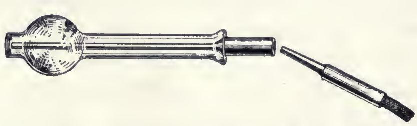

Fig. 335.—Aural ion transfer electrode. (Courtesy of the General Electric *X*-ray Corp.)

Chronic Suppurative Otitis Media.—Chronic suppurative otitis media, in the absence of bone necrosis, polyp or marked granulation tissue formation, or cholesteatoma, is sometimes markedly benefited by use of the water-cooled ultraviolet lamp, applied two or three times a week with the following technique: (*a*) The canal and middle-ear are very carefully cleansed by dry or alcohol cotton applicators and capillary suction, avoiding any irrigation; (*b*) 2 per cent mercurochrome solution is dropped into the canal, with the head well inclined to the opposite side (after ten minutes the excess solution is swabbed out); (*c*) ultraviolet is applied with or without a suitable quartz rod applicator in the canal, beginning with a dose of one minute, and increasing it slightly with each treatment, without blistering; in time doses of eight to ten minutes may be given.

Another method of use in uncomplicated chronic middle-ear suppuration, especially with large drum perforation, is zinc iontophoresis. The method can scarcely be expected to give permanent results when there is polyp or much granulation tissue formation, bone caries, chronic mastoiditis, cholesteatoma and recurrent infection *via* the Eustachian tube from the nose and pharynx. The technique is as follows: (*a*) The canal and middle-ear are carefully cleansed by capillary suction and cotton applicators wet with 0.2 per cent zinc sulphate solution, 1 grain to 1 ounce of distilled water; (*b*) with the patient lying on the opposite side, the ear and canal are filled with the same solution; (*c*) the positive pole of a source of galvanic current is connected to a zinc wire placed in the solution in the canal, protecting the latter by means of a hard rubber speculum; (*d*) the negative pole of the apparatus is connected to a large electrode of the moist sponge type placed on the skin of the arm or back; (*e*) 2 to 4 milliamperes of current is passed for from ten to fifteen minutes. One treatment may suffice to dry up the discharge; if not, it may be repeated twice a week; but if the discharge continues after three or four treatments the method will probably not succeed.

Fig. 336.—Application of aural ion transfer electrode. (Courtesy of the General Electric *X*-ray Corporation.)

Chronic Catarrhal Otitis Media, Otosclerosis and Auditory Nerve Deafness.—These are conditions which are widely separated pathologically, and yet may be considered together because they all produce at least two symptoms in common, tinnitus and diminished acuity of hearing. The most essential treatment in all is to remove the underlying cause, if that is possible; the general health should be improved using full-body ultraviolet baths. The local application of the deeply penetrating heat of medical diathermy should theoretically soften the scar tissue formed in the tympanum in the first disease, perhaps slow up the spongy new-bone formation characteristic of otosclerosis, and slow or prevent the degeneration of the auditory nerve in neuritis, by increasing the local blood supply and promoting lymph drainage. Medical diathermy is applied in several ways. (*a*) Metal electrodes may be placed within the ear canals of each side;

(*b*) with the metal cuff electrode around each wrist, the tip of the patient's own forefinger is inserted into the canal as an electrode; (*c*) wire electrodes may be inserted in cotton wet with 10 per cent saline solution packed into the ear canals; (*d*) perhaps the best method is the use of two oval plate electrodes, 1½ by 2 inches in size, one over the mastoid of the side to be treated and the other on the opposite cheek. Sufficient current is passed to create a comfortable sensation of heat, without causing vertigo or nausea; the treatment should last from ten to twenty minutes, and be repeated two or three times a week for long periods. As to actual results obtained, no great promises may be made, although encouraging reports have come from careful observers.

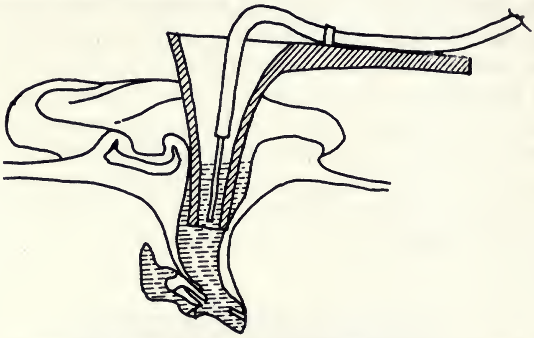

FIG. 337.—Schematic diagram of zinc iontophoresis of chronic middle-ear disease.

The deep heating effect of short-wave diathermy may be tried in these stubborn conditions. It is given as described for furunculosis, above. When both ears are affected, 4-inch rubber-covered electrodes, enclosed in sterile paper, may be applied against both ears at once, compressing both pinnæ against the skull, and the current passed for ten to twelve minutes. Gentle heat is felt in both sides. The treatment is given two or three times weekly and must be persisted in for several months.

DISEASES OF THE NOSE AND NASAL ACCESSORY SINUSES

The External Nose and Nasal Vestibule.—Acute and Chronic Dermatitis.—Acute and chronic dermatitis occurs here, usually with infections of the interior of the nose or sinuses; the essential treatment is that of the causative lesion. They are often benefited by the use of luminous heat and ultraviolet radiation, as described for similar conditions in the pinna and external auditory canal.

Furunculosis.—Furunculosis of the nasal vestibule may be treated as outlined for similar conditions in the ear canal. Furuncles in this area should never be pinched or squeezed, nor opened until they point, for fear of setting up a spreading septic thrombophlebitis of the angular vein, leading to cavernous sinus thrombosis.

The Nasal Chambers.—Acute Rhinitis.—Acute rhinitis is often much benefited by applications of luminous heat or infrared radiation to the entire face and head for twenty minutes every two hours. Intranasal ultraviolet may also be applied with the water-cooled mercury vapor lamp, with a speculum or through a suitable quartz rod applicator, beginning with doses of one-half minute or less, once daily; the length of exposure may be slowly increased with succeeding doses. This method is perhaps even more efficacious if employed following nasal tamponade with one of the colloidal silver solutions. Full-body ultraviolet baths may be used during convalescence and to aid in prevention of further attacks.

Chronic Generalized Hypertrophic Rhinitis and Chronic Atrophic Rhinitis.—These conditions are both aided symptomatically by: (*a*) Intranasal ultraviolet radiation after colloidal tamponade, as described above; (*b*) intranasal ionization with a silver colloid solution or zinc sulphate solution (the positive electrode is of bare copper or zinc wires wrapped in cotton dipped in the solution used and inserted within the nose) and 3 or 4 milliamperes of galvanic current passed for five minutes in each side of the nose as an average treatment; (*c*) in resistant cases the interior of the nose may be treated by application of the Oudin current with a non-vacuum electrode which is gently rubbed over the mucosa for ten minutes two or three times a week.

Recently chronic atrophic rhinitis has been treated by some workers by intranasal ionization with mecholyl. This vasodilating drug brings about increased secretion and tends to lessen crust formation and so to decrease the fetor. The nasal cavities are cleansed of secretion, anesthetized by spraying twice with any suitable anesthetic solution, and then packed with cotton pledgets moistened with 1 to 500 solution of mecholyl. The cord from the positive pole of the galvanic current apparatus is clipped to the cotton left protruding from the nostrils. The negative pole is connected to a 6- by 8-inch piece of block tin, which is placed centrally upon an 8- by 10-inch piece of absorbent cotton ½ inch thick, and wet with normal saline solution. The whole is firmly bandaged to the bare skin of the patient's forearm. The current is turned on and very slowly increased to 15 milliamperes. This is allowed to pass for twenty minutes, and then slowly decreased to zero. The packing and electrodes are removed. The treatment is given once or twice weekly.

Chronic Localized Hypertrophies.—Chronic localized hypertrophies in the nose, commonly seen as hypertrophy of the anterior or posterior ends or of the whole body of the middle and inferior turbinates, may very easily be removed under local anesthesia by means of an insulated nasal snare, employing combined cutting and light coagulating current. Reduction in size of the body of the inferior turbinate is best accomplished by submucous coagulation with the double-needle electrode, which is inserted beneath the mucosa under local anesthesia and a delicate coagulating current passed from one needle to the other. This produces a scar which reduces the hypertrophy with a minimum of damage to the turbinate mucosa.

Vasomotor Rhinitis and Hay Fever.—Vasomotor rhinitis and hay fever are best treated by the removal of the substance or substances to which the patient is hypersensitive from his environment, or his desensitization to them if this is possible. To aid in symptomatic relief the following methods are used: (*a*) Full-body baths of ultraviolet twice a week; (*b*) intranasal ultraviolet with the water-cooled lamp, as described above; (*c*) intranasal ionization with the silver colloid solution, as described previously; (*d*) intranasal application of the Oudin current, as explained above (this is best applied in the intervals between attacks); (*e*) medical diathermy may be applied by means of two plate electrodes placed on the side of the face, so that the nasal chambers lie in the path of the current, being very careful to avoid "edge effects."

The treatment of nasal allergy by the *zinc iontophoresis* of the nasal mucosa has been widely used in the past few years. It produces a well-marked inflammatory reaction in the mucosa, with destruction of cilia, desquamation of the epithelium, vascular congestion and cellular infiltration in the submucosa. In time much of the epithelium regenerates, although the cilia may be lost, and a submucous fibrosis results. Whether any permanent damage is done to the mucosa which might lead to atrophy in later years has not been fully decided, but it seems quite unlikely in the light of recent proof of the great power of regeneration to normal structure and function of the nasal mucosa, even after its complete surgical removal, as from the sinuses.

Technique of Zinc Iontophoresis.—Any source of a smooth galvanic current, which can be accurately measured with a milliamperemeter, and controlled by a fine rheostat, may be employed. The nasal cavity is anesthetized by spraying it two or three times with any suitable anesthetic solution. The interior of the nose is filled by packing it with long, slender pledgets of cotton wet with 1 per cent zinc sulphate solution. The olfactory area must not be so packed, or anosmia will result, and may persist for many months. A space is left between the inferior turbinate and the septum, in which, among the pledgets, a slender zinc electrode is introduced after being lightly wrapped in cotton; the bare metal must not touch the tissues or a burn will result. A simpler method is to clip the cord firmly to the wet cotton left protruding from the nostril. The positive pole is connected to the nose. The skin of the forearm is cleansed of oil with carbon tetrachloride or ether, and an 8- by 10-inch piece of absorbent cotton, ½ inch thick, thoroughly wet with normal saline solution, is placed on the arm. Centered on the cotton, a piece of block tin 6 by 8 inches, is applied to fit the shape of the arm smoothly, and the cord from the negative pole is attached to it firmly. The whole is snugly bandaged to the arm; burns will result unless there is smooth and even contact over the whole electrode.

The current is turned on, and very slowly increased to 10 milliamperes. The patient will complain of a salty, metallic taste, and free salivation occurs; he is given a pus basin into which to expectorate. There should be no painful sensation in the nose or arm; if this occurs, the current must be shut off at once, and search made for a point of contact of bare metal with skin or mucosa; this must be remedied or a burn will result. The current is passed for ten to twelve minutes and then slowly decreased to zero. The electrodes and packing are removed. The nasal mucosa is seen to be covered with a white deposit. Within a short time, the patient will have some neuralgic pain in the face; he must be given 10 to 20 grains of phenacetine or 1 grain of codein, and instructed to lie down and apply cold compresses to the face. The pain passes away in eight to twelve hours. The nasal cavity becomes filled with a rubbery, white fibrin, which is adherent to the mucosa. It loosens and can be removed by blowing the nose, or with forceps, after the fourth day.

Instead of nasal packing, the nasal cavity may be filled with a semi-fluid jelly of gum tragacanth, containing 1 per cent of zinc sulphate. It is supplied in collapsible tubes with long nasal tips. The jelly must be prevented from entering the olfactory area by inserting between the middle turbinate and septum, up to the roof of nose, a 3-inch long piece of petrolatum gauze packing. This is removed from the nose after the treatment, and the jelly blown or sucked out. The jelly is sufficiently stiff so as not to run into the pharynx. The positive electrode is a hard rubber tip which fits into the nostril and from which protrudes a piece of zinc wire 2 millimeters long. The wire lies in the jelly and must not touch the tissues. The tip is held in the nostril by the patient, or it is suspended from a head band made for this purpose. The arm electrode and the method of applying the current is the same as with packing; the jelly is much more comfortable for the patient than packing.

In seasonal hay fever, the treatment is best given just at the commencement of the season. The symptoms are usually relieved at once, and do not recur for six to eight weeks, or longer. The treatment must be repeated each year for most patients. Properly applied, more than 75 per cent of hay fever sufferers will be relieved of 90 per cent of their symptoms. Both sides of the nose may be done at one sitting, although this causes a more severe reaction than when one side is done, and the second treated after an interval of five to seven days.

In the more chronic, non-seasonal forms of nasal allergy, usually termed vasomotor rhinitis, ionization may be done at any time, and affords a very good chance for relief from the most troublesome symptoms for periods of three to six months or longer. It is most useful when symptoms persist despite allergic control, or when the patient is sensitized to inhalant proteins which he cannot avoid.

Nasal Synechiæ.—Nasal synechiæ are easily divided under local anesthesia by coagulating the bands with a suitable nasal needle electrode and a dispersive electrode on the arm or back. If the coagulum produced is left *in situ* until it sloughs away there is little probability that the synechia will reform.

Epistaxis.—Epistaxis, due to rupture of small vessels on the lower and anterior portion of the septum or other accessible areas, is readily stopped and recurrence often prevented by coagulating the area under local anesthesia with a light current.

Lupus and True Tuberculosis of the Nose.—These conditions are rarely seen. The usual local treatment comprises: (*a*) Repeated treatment with the mercury vapor lamp, with a speculum or quartz rod applicator; (*b*) destruction of lupus or tuberculous granulations with the coagulating current and the needle nasal electrode.

Benign and Malignant Growths of the Nose and Sinuses.—These growths may require electrosurgery, but because of the surgical skill and judgment required this is best left for the specialist.

The Nasal Accessory Sinuses.—**Acute Sinusitis.**—Acute sinusitis if often greatly helped by: (*a*) Luminous heat or infrared radiation of the face; for the relief of pain and promotion of drainage twenty to thirty minutes every hour is not too great a dosage; (*b*) medical diathermy—for the antrum or frontal, a plate electrode moulded to fit closely is applied over the sinus, with a larger dispersive plate on the back of the neck, and for the ethmoids and sphenoid plates of equal size are placed on the sides of the face; the heating current is made to pass through the sinus being treated and treatment is given once or twice daily, for twenty to thirty minutes at each session. The strength of the current must be kept within the limit that gives the patient a pleasant sensation of heat only. It must be noted that before medical diathermy is applied the best possible drainage of the affected sinuses must be secured by the usual intranasal medication, suction, irrigation, tampons, etc., or the heat may increase the pain of the inflamed sinus.

Short-wave diathermy applied over painful and suppurating sinuses is welcomed by the patient. It provides very pleasant heat and pain is often relieved. The short wave is much easier and more comfortable of application than the long-wave diathermy, which demanded close fit of metal electrodes, and often produced faradic sensations. The patient is placed in a wooden chair between the arms of the electrode stand. A 4-inch circular condenser pad, wrapped in sterile paper or a thickness of Turkish towel is fitted over the forehead or cheek to be heated. The air space, or felt or glass space type of electrode may be used. With any form of electrode, current concentration and undue heat over bony prominences or protruding soft parts must be avoided, or burns will result. The second electrode should be much larger, spaced with dry felt or towel, and applied firmly against the back, chest, or under the buttocks. The second electrode may be simply suspended 2 inches from the back, chest or shoulder, from the second arm of the stand. The heat applied must always be well within the level of tolerance, and maintained for fifteen to thirty minutes, once or twice daily.

Chronic Sinusitis.—Chronic sinusitis occasionally calls for electrotherapy. Medical diathermy will aid in the relief of pain in acute exacerbations, and is to be applied as outlined. It will not help the reduction of mucosal hypertrophies and polyps. Zinc iontophoresis has a limited use in promotion of the healing of the antrum, frontal or sphenoid sinuses after they have been surgically drained, etc. The head is so placed that the sinus to be treated can be filled with 0.1 per cent zinc sulphate solution, into which a zinc wire is placed so that it is not in contact with the nose; this is connected to the positive pole of the galvanic current apparatus. A dispersive electrode is placed on the back of the neck or arm, and 2 to 5 milliamperes of current passed for ten or fifteen minutes.

Nasal Polyps.—Nasal polyps may be removed with the cutting current applied by the insulated nasal snare, such as described for the removal of turbinate hypertrophies.

Granulation Tissue.—Granulation tissue following intranasal operations is readily removed by application of the desiccating or very light coagulating current, under local anesthesia, with a suitable nasal electrode.

DISEASES OF THE PHARYNX

Acute Pharyngitis.—Acute pharyngitis is much helped symptomatically by luminous heat applied to the entire head and neck twenty to thirty minutes every two or three hours; infrared radiation may be used similarly. Diathermy also may be applied by plate electrodes on each side of the neck, with care to avoid "edge effects;" only enough current is passed to cause a comfortable heat sensation, for thirty minutes once or twice daily. Short-wave diathermy may be similarly used. The air spaced or glass or rubber-covered electrodes of the 4-inch circular size are placed on each side of the neck, centered below the angle of the jaw. Mild heat is applied for twenty minutes once or twice daily. The usual internal and local antiseptic or astringent medication must not be neglected.

Chronic Pharyngitis.—Chronic pharyngitis calls first for the discovery and removal of the underlying cause or causes. Symptoms are often relieved by medical diathermy applied across the pharynx and the tissues of the neck, as described above. The general health is improved by full-body ultraviolet baths. In addition, chronically congested areas, such as the lateral pharyngeal folds, pharyngeal follicles ("granulations") and the vault or posterior wall of the nasopharynx, may be given mild erythema doses of ultraviolet radiation by means of the water-cooled lamp and suitably shaped quartz rod applicators; burns must be avoided, and the treatment repeated once a week.

Hypertrophied and Infected Lymphoid Tissue.—Hypertrophied and infected lymphoid tissue in the pharynx, such as follicles, lateral folds, etc., is best treated by electrocoagulation. The current is applied by means of insulated electrodes of the needle type, or small button, on the surface, with a dispersive electrode of large size on the back or under the buttocks. The latter may be dispensed with if the coagulation is done by means of the double-needle electrode, in which each needle carries the current, and is separated from the other for 3 or 4 millimeters. The needle-points are plunged into the tissue under the guidance of vision, and enough current passed to slowly coagulate an area of several millimeters in diameter. Small areas may be done under local anesthesia, not too much at a time, and the process repeated until the hypertrophy is destroyed. Extensive areas may be destroyed in one sitting if performed under chloroform anesthesia.

Hypertrophy of the Adenoid.—Hypertrophy of the adenoid calls for complete surgical removal. To date, as far as the author knows, no practicable instrument has been developed for the removal of the adenoid by means of the cutting current.

Hypertrophied Remnants of the Adenoid.—Hypertrophied remnants left after poor surgical removal, especially those so commonly found in Rosenmüller's fossa and about the Eustachian tube mouth, are very readily and bloodlessly removed by coagulation *in situ.* A palate retractor or nasopharyngoscope of the Yankauer type is used, and the current applied by multiple puncture with suitably shaped needle electrodes; a large dispersive electrode is placed under the buttocks or on the back. Chloroform anesthesia is used and all the infected tissue coagulated at one sitting.

Acute Tonsillitis.—Acute tonsillitis is helped symptomatically by luminous heat to the entire head and neck, twenty to thirty minutes three or four times a day. Direct application of the water-cooled ultraviolet lamp by a curved quartz rod to the tonsils is sometimes of striking benefit. Burns must be avoided by beginning with one-half minute dose and increasing one-half minute daily. Pain and soreness due to swelling of the cervical lymph glands may be relieved by medical diathermy, given by plate electrodes on the sides of the neck; a comfortable heat for thirty minutes once or twice a day is sufficient. Short-wave diathermy may be applied for the relief of pain and of dysphagia, as has been described for acute pharyngitis, above. Since acute tonsillitis is practically always due to the hemolytic streptococcus, the essential treatment is proper medication with sulfanilamide, given at once in full dosage, and continued until the symptoms disappear.

Chronic Tonsillitis and Hypertrophy of the Tonsils.—This is best treated by surgical methods.

Electrosurgical Removal of the Tonsils.—This is accomplished in one of two ways: (*a*) *Coagulation of tonsils in situ* by the method of multiple punctures. This is the method which has been most widely used. It is performed under local anesthesia. The usual method of securing the anesthesia is to paint the tonsil several times at intervals of five minutes with an anesthetic solution applied on very small cotton swabs. The author prefers a solution of equal parts of aniline oil, absolute alcohol, and alypin powder. Novocaine or other similar solutions may also be injected, if used in small quantities, and at least fifteen minutes allowed to elapse between the injection and coagulation, to permit the solution to diffuse through the tissues, and to allow the edema caused by the injection to subside.

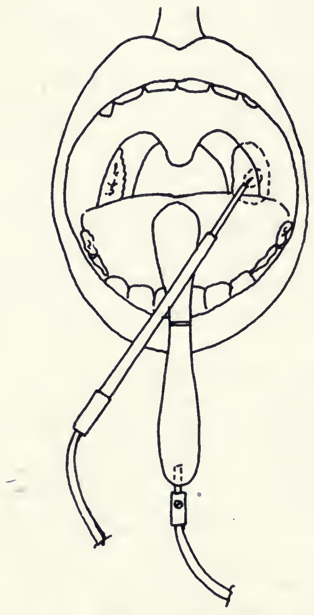

Fig. 338.—Electrocoagulation of tonsil by needle electrode, using metal tongue depressor as dispersive electrode.

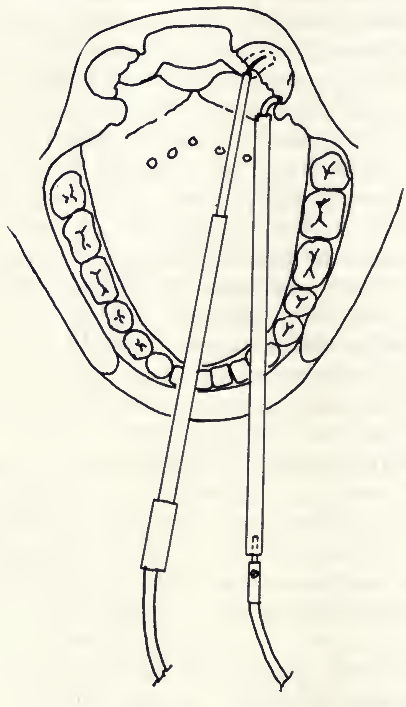

Fig. 339.—Electrocoagulation of tonsil by electrode, using insulated metal pillar retractor as dispersive electrode.

The active electrode most commonly used is a thick, curved needle in an insulated handle. The dispersive electrode may be the large metal plate on the bare back or under the buttocks; or a metal tongue depressor, or pillar retractor may be employed for the double purpose of exposing the tonsil, and as a dispersive electrode, with no danger of burning the patient or short-circuiting the diathermy machine if the operator avoids contacting the bare metal active electrode and the dispersive electrode while the current is flowing.

The biterminal method of tonsil coagulation consists of employing a double needle tonsil electrode; two short curved needles are insulated from each other within a suitable handle; the points are separated for 4 millimeters; each needle carries the current, and coagulation takes place between and around the two points. No dispersive electrode is necessary.

In use, when anesthesia is complete, the active electrode is punctured into the tonsil under the guidance of vision, with the area illuminated with head lamp or reflected light, the tongue depressed or the anterior pillar retracted as the case may require. When the needle point is in the tonsil tissue at the desired spot, a light coagulating current is passed by closing the foot switch of the machine until an area of 4 millimeters of tissue about the needle turns white; the current is then shut off and the needle withdrawn. Another area is then treated similarly. While there has been some discussion as to the exact sequence in which the tonsil should be coagulated, it seems to the author that coagulation should begin at the center of the surface of the tonsil, and then be carried forward, upward, and backward in successive steps until the capsule is reached. These steps are shown diagrammatically in Figures 338 and 339.

The number of areas treated at any one sitting must vary with circumstances. The operator must remember that if too much coagulation be done at a session, considerable soreness will result; if large areas are coagulated and the slough so created comes away in large portions, bleeding may result. The author feels that four to five punctures at each treatment are sufficient. Only one tonsil is treated at a time; the process is begun on the second tonsil in a week, and the coagulation is not repeated on the first tonsil until soreness, reaction, and the slough have disappeared; this usually takes ten days to two weeks. Thus each tonsil is treated every two weeks, and individual treatments are given once a week on alternate tonsils. After-treatment is simple, and calls only for soft, bland food for two days after each session, and the use of a throat lozenge containing a local anesthetic.

The number of treatments required to completely remove the tonsils will naturally vary with the size and consistence of the tonsils, on the amount of coagulation that can be done per treatment, and on regularity of the sessions. In the experience of the author the rather firm tonsil found in most adults will require ten treatments for complete removal; this means twenty treatments for both tonsils, and these are spread over a period of at least four months; this length of time is the one great disadvantage of the method.

While some authors have not found incomplete removal of the tonsils by this method apparently harmful, the author can only be guided by analogy with the results noted after incomplete removal by the surgical, non-diathermic method, in which very many competent observers have stated that incomplete removal of infected lymphoid tissue is very objectionable. One must have for his aim the thorough removal of every visible and palpable bit of tonsil tissue. This requires patience and skill, especially in the patient with very large, or very fibrous tonsils, with the sensitive throat in which any procedure is carried on with difficulty; in these patients, one needs all the skill necessary to perform complete *surgical* tonsillectomy under local anesthesia.

The method of electrocoagulation by multiple puncture is especially adapted for the removal of small portions of tonsil left after ordinary tonsillectomy; the technique is exactly the same as that outlined above.

(*b*) Enucleation of tonsils by the cutting current or combined cutting and light coagulating currents. Local anesthesia is used in adults, and chloroform in children. An insulated snare, the wire of which carries the current, is employed. The dispersive electrode is a very large plate on the back or under the buttocks. The tonsil is engaged in the instrument so that when the wire is tightened and the current applied the wire cuts the tonsil from its bed along the line of the capsular attachment, without damaging the pillars, tongue, etc. Enough coagulating current is used to seal small blood-vessels; if larger vessels are opened the bleeding-point is seized with an ordinary tonsil hemostat and the coagulating current applied through the clamp to seal the open vessel. The advantages of this method are that it completely removes the tonsil at one sitting, and that it is relatively or completely bloodless; the operation is quickly done and the anesthesia is thus short. Reaction and soreness following electrosurgical

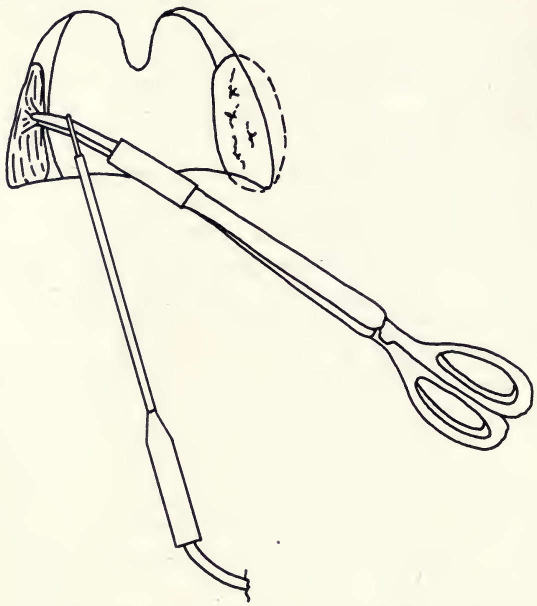

FIG. 340.—Electrocoagulation of bleeding-point in tonsil fossa by means of insulated hemostat and needle electrode.

tonsillectomy by this method is no greater than with ordinary dissection. There is some possibility of secondary hemorrhage with the separation of the slough which takes place within from five to ten days.

Peritonsillar and Retropharyngeal Abscesses.—These may be opened with the cutting current applied by means of the needle electrode and a dispersive plate on the back or buttocks. The current should be used to incise the mucosa and submucosa only; if pus is not encountered at this level the abscess should be opened by the insertion of blunt forceps or scissors, to avoid the damaging of larger blood-vessels.

Elongation of the Uvula.—Elongation of the uvula is readily and bloodlessly cured by amputation of the redundant portion by the insulated snare and the cutting current, under local anesthesia.

Hypertrophy of the Lingual Tonsil.—Hypertrophy of the lingual tonsil is readily reduced by multiple punctures and coagulation under local anesthesia. The single needle electrode is used with the dispersive electrode on the back; a metal tongue depressor or the laryngeal mirror may also be used as the dispersive electrode, if care is taken not to touch the two electrodes while the current is on. The double-needle electrode may also be used without any dispersive plate. Light coagulation is used, and repeated sittings at intervals of seven to ten days until the hypertrophy is reduced are advised.

Varicose Lingual Veins.—Varicose lingual veins may be coagulated by the method described for the lingual tonsil.

DISEASES OF THE LARYNX

Acute Laryngitis.—Acute laryngitis may be treated by electrotherapy, in addition to the usual measures of vocal rest, and local and internal medication. Application of luminous heat, or infrared radiation, over the neck and chest may be made for twenty to thirty minutes every two or

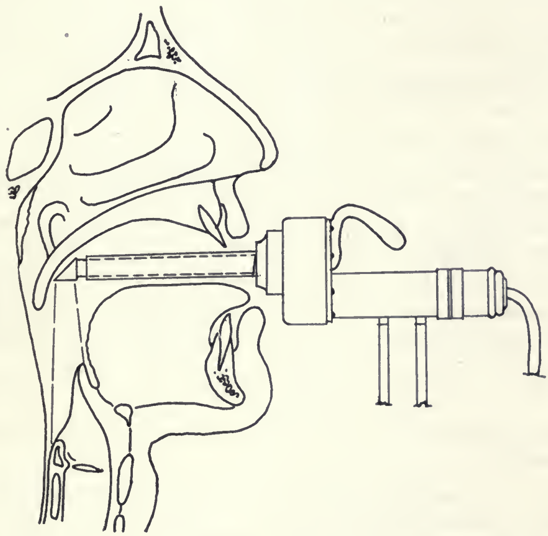

Fig. 341.—Applications of ultraviolet radiation from water-cooled lamp to larynx.

three hours. Medical diathermy may also be applied by means of plate electrodes on the sides of the neck, being careful to avoid "edge effects." Because of the difficulty of maintaining an electrode directly over the larynx, it is best not to attempt it, as a burn of the skin may result. Enough current is passed to maintain a comfortable heat for twenty or thirty minutes once or twice a day.

Short-wave diathermy often gives prompt relief from the soreness and discomfort of acute laryngitis. It may be applied by placing 4-inch circular electrodes, of the air, glass or felt space type on opposite sides of the neck, so that the larynx lies between them. Edge effects across the narrow anterior part of the larynx must be avoided. A very comfortable method is the use of the induction cable, which is wrapped several times about the neck over ½ inch of dry Turkish towel or felt spacing. A comfortable heat for fifteen or twenty minutes is given. (Fig. 165.)

Chronic Laryngitis.—Chronic laryngitis is best treated by the discovery and removal of the underlying cause; this usually calls for a very close and extensive study by the specialist. It may be helped symptomatically by the use of luminous heat, infrared radiation and medical diathermy, as described above for acute laryngitis. In addition, ultraviolet radiation from the water-cooled lamp may be applied by means of a suitable quartz rod and prism in the mouth and pharynx, so placed that the radiation passes down to the larynx. Very great care must be used to prevent even slight burns, because of the danger of reaction, with swelling and interference with respiration, that may result. The doses at the beginning must be very short, ten or fifteen seconds, increasing slowly, and giving the treatment twice a week is advisable.

Laryngeal Tuberculosis.—Laryngeal tuberculosis is best treated by the laryngologist and pulmonary specialist, since it is always secondary to pulmonary phthisis. Electrotherapy is of great aid in well-chosen cases. Medical diathermy may be used as for acute laryngitis, to help relieve local symptoms. Ultraviolet radiation to take the place of sunlight applied to the larynx by means of mirrors has given good results in some hands. It is given, as described above, with the quartz rod and prism, with great care to avoid reaction and edema. For the destruction of tuberculous granulation tissue, the treatment of tuberculous ulcers and the reduction of edematous and infiltrated tissue in the larynx, the desiccating and coagulating currents are applied with suitable insulated needle electrodes, either by suspension laryngoscopy or peroral direct laryngoscopy. Since such procedures require special skill, they are best left to the specialist.

Benign and Malignant New Growths of the Mouth, Pharynx and Larynx.—These growths are being treated by electrosurgical removal by many. Like nasal new growths, this is best left for the specialist or surgeon, who has the technical skill to attack what often prove to be formidable procedures.

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CHAPTER XXXV

DISEASES OF THE EYE

General Considerations. Dangers. Eyelids and Conjunctiva. Cornea, Uveal Tract and Retina. Ocular Syphilis. Electrosurgery of the Eye.

General Considerations.—Physical measures offer valuable aid in the management of many ophthalmological conditions. Dramatic results have been described in corneal ulcers with ultraviolet irradiation while artificial fever therapy has opened up a new path in the effective treatment of many forms of ocular syphilis. Fever therapy, infrared radiation and diathermy have been found useful for relief of pain and promotion of resolution in acute ocular inflammatory conditions. General ultraviolet application is indicated for tuberculous and phlyctenular conditions. Zinc ionization is of value within a limited scope. Electrodesiccation is an ideal method to remove small neoplasms from the tissues of the eye with a perfect cosmetic result, while other forms of electrosurgery have been successfully employed in a variety of conditions.

Dangers.—Exposure of the unprotected eye to ultraviolet radiation results in a painful inflammatory reaction already mentioned in Chapter XIX as photoöphthalmia. Duke-Elder[5] regards it as a form of keratitis rather than of conjunctivitis. He emphasizes the fact that while exposure of a diseased part of the cornea for therapeutic purposes and a subsequent inflammatory reaction may be desirable, exposure of the lens is to be avoided under all circumstances. Hence the necessity that the lens be excluded from the path of incident rays in any technique of phototherapy. Law[13] has cautioned against overexposure to infrared radiation; he is of the opinion that such overexposure may occur either by direct penetration of the rays or secondarily by the heat transmitted to the lens by the iris, which presents an efficient absorptive surface for heat radiation.

Eyelids and Conjunctiva.—In *acute conjunctivitis,* after removal of all immediate causes, luminous heat or infrared radiation is advisable; it is applied to the closed eyelids of the patient from a distance where it feels just pleasantly warm, for twenty to thirty minutes and is repeated at least three times daily. It usually results in prompt relief of pain and discomfort and in the gradual subsidence of the other signs of inflammation. In acute gonorrheal conjunctivitis for the first twenty-four to forty-eight hours ice cold compresses are most effective but they never should be applied continuously and should be superseded by local heat after the initial period.

In refractive cases of *chronic conjunctivitis, blepharitis, trachoma* and *vernal catarrh,* local ultraviolet irradiation with a quartz applicator has been recommended (Hollender and Cottle,[8] Duke-Elder[5]). A third-degree erythema is employed which results in desquamation and rapid regeneration of the mucous membrane. The treatment is applied by contact to the everted inner corneal surface of the conjunctiva while the cornea is protected against the rays. The process is repeated until a fresh and unscarred mucous membrane is produced; this compares very favorably with the usual cicatrization which results after prolonged silver or other caustic application.

In *hordeolum* luminous heat may be applied in prolonged and repeated doses to bring the stye to a head. Ardent users of static electricity claim that the application of the static brush discharge is a specific in aborting a beginning stye through the powerful actinic and absorptive effects of the brush discharge.

For *chalazion* local ultraviolet application is sometimes of value (Hollender and Cottle[8]); in stubborn cases electrodesiccation is indicated. This may be also utilized to destroy the remnants after the chalazion has been incised and curetted. In angiomas, trichiasis, either electrodesiccation or electrolysis may be employed.

Stenosis of the lachrymal duct has been treated with the negative pole of the galvanic current through special probes devised by Jarecky (quoted by Hollender and Cottle) and good results have been claimed following the simultaneous dilatation and electrolysis.

Cornea, Uveal Tract and Retina.—*Corneal ulcer* responds favorably to ultraviolet radiation according to Duke-Elder and Nugent.[18] Nugent concludes that ultraviolet irradiation is efficient because of the transparency of the cornea to ultraviolet rays and because corneal necrosis is chiefly due to bacterial invasion. Irradiation from a suitable ultraviolet source accomplishes sterilization of the necrotic and perinecrotic area of the ulcer; regeneration of new epithelial cells to cover the area is quite rapid; scar formation is greatly reduced and the resulting scar is thinner.

A special ultraviolet lamp has been designed by Birch-Hirschfeld.[2] It is a carbon arc lamp with a filter of uviol glass and a quartz lens system which allows the focusing of a fine bundle of light on the corneal lesion. The uviol filter absorbs all short-wave lengths below 2850 Angstroms and also some of the infrared rays and an extra quartz cell containing distilled water absorbs the rest of the heat rays. An application of from three and a half to six minutes is repeated from three times a day to three times a week, depending on the extent of infection and the amount of discharge from the necrotic surface.

Law[13] has designed a lamp which is much less expensive and for which he claims equal effectiveness. Its ultraviolet source is a small mercury vapor lamp, and the optical system is composed entirely of quartz; an iris diaphragm is included in the system. By this means a concentrated beam, rich in ultraviolet light, can be directed accurately onto a lesion of the cornea or other parts of the anterior segment of the globe.

Zinc ionization has been recommended for corneal ulcers by Erlanger,[6] Friel[7] and others. The technique consists of anesthetizing the eye with a cocaine solution, cleansing the ulceration and applying to it a pad of cotton, saturated with a 0.25 per cent solution of zinc sulphate. A zinc rod connected to the positive pole of a galvanic source is pressed against the pad and a current of 1 milliampere is applied for five minutes. Erlanger also advocates the use of ionization (histamine 1 to 10,000 solution or acetylcholin 1 to 200) to the sclera in cases of choroido-retinitis for relieving spasm of the small arteries and to improve circulation.

Cauterization by regulated heat is a standard procedure. The thermophore of Shahan consists of an electrical heating unit and metal applicators of various size and shape. The fine metal tip selected for a lesion is heated to a set degree of temperature and is applied by direct contact to the anesthetized corneal surface for a minute or a fraction thereof. High temperature (up to 165° F.) is recommended to stop progress of an ulcer and lower temperature to stimulate absorption. It was originally advocated as a treatment for serpiginous ulcer of pneumococcus origin but it also proved efficacious in the ulcer of dendritic keratitis and ring ulcer.

Artificial fever therapy has been reported on favorably by Whitney[22] in the treatment of corneal ulcer and acute iritis. Recurrent abrasions of the cornea are better treated by ultraviolet than by any other means according to Law.[14]

Phlyctenular keratitis, kerato-conjunctivitis and *tuberculous iritis* respond to general ultraviolet therapy. Cases of phlyctenular conjunctivitis as a rule clear up rapidly after a course of general irradiation. Ill-nourished children in whom the condition has recurred chronically for a number of years need local applications of ultraviolet to the conjunctiva, together with general light baths. (For technique, see Chapter XIX.) According to Duke-Elder, tuberculous iridocyclitis is notoriously one of the most difficult eye diseases to treat; yet it responds often dramatically to general ultraviolet irradiation, provided it is begun at a reasonably early stage of the disease. In tuberculous forms of choiroiditis and scleritis, the results are similarly satisfactory.

Vitreous Opacities, Cataract and Glaucoma.—In vitreous opacities good results have been claimed in some cases by both the galvanic current and diathermy. Bauwens[1] states that diathermy is indicated in deep opacities, keratitis punctata and adhesions between the lens capsule and the iris. French clinicians advocate the galvanic current for opacities and flocculi of the vitreous.

Diathermy and the galvanic current should be administered over the closed lids. For galvanism a well-moistened electrode of suitable size and shape is applied over the affected eye and a dispersive pad electrode is held under the nape of the neck; a current strength not exceeding 5 milliamperes is applied for fifteen to twenty minutes. For diathermy, bare metal electrodes are employed with a current strength not exceeding 400 milliamperes and always within careful limits of individual sensibility. The universal headband of Hollender is offering a convenient means of treating one or both eyes and there are also available double eye electrodes (Fig. 342). The efficient heating of the contents of the orbit by diathermy was demonstrated by the experimental studies of Moncrieff, Coulter and Holmquest.[17]

As to treatment of glaucoma by galvanism and diathermy, there is theoretical objection to the use of both because the increase of circulation may increase the tension. This was also proven experimentally. On the other hand, careful clinical observation (Hollender and Cottle) has shown that they have given symptomatic relief in early cases where emergency surgery is not called for. Lyle[15] in a few cases studied found that tension was not increased in either normal eyes, nor in those with chronic hypertension, while the pain was relieved.

In acute inflammatory diseases of the eye, intensive prolonged hyperthermy relieves pain promptly and may restore vision, totally or partially, depending on duration of the infection and extent and number of treatments, according to Knight *et al.*[11] They recommend five-hour sessions of fever at 105° F. at three to five-day intervals, continued, if the patient's condition permits, to the point of maximal improvement. Temperatures of 106° to 107° F. for longer periods with concurrent use of sulfathiazole are indicated for gonococcic iniectfons.

Fig. 342.—Two cup eye electrode: Cup is filled with cotton saturated with saline solution for straight galvanism, or with medicated solution for ion transfer. (Courtesy of the Teca Corporation.)

Ocular Syphilis.—Culler and Simpson[4] hold that the various manifestations of syphilis in the eye rank with those of involvement of the central nervous system in their reluctance to yield to antisyphilitic chemotherapy, and the inadequacy of orthodox treatment has been repeatedly demonstrated. A series of 58 patients with various manifestations of ocular syphilis have been treated with approximately fifty hours of fever with temperatures above 105° F. in ten weekly sessions of five hours each, and a course of thirty injections of bismarsen was given in conjunction with the fever treatments. Best response was seen in exudative lesions of ocular syphilis, interstitial keratitis, exudative uveitis, active optic neuritis, neuroretinitis and choroiditis. Atrophy of the optic nerve is no contraindication to fever therapy and if it is associated with foci of active infiltration along the optic tract, they probably will respond. Culler and Simpson are of the opinion that early manifestations of syphilis offer the greater field of usefulness for artificial fever therapy combined with specific therapy, with a view to prevention of the often disastrous ocular complications.

In advanced *optic neuritis*, the galvanic current has been advocated by German clinicians and also by the late Granger who stated that approximately 50 per cent of the cases treated by his technique were benefited.

Glass or metal double eye cups are filled with moist cotton adjusted to the closed lids and connected to the negative pole of a galvanic source. A dispersive pad, 4 by 5 inches is placed over the back of the neck and connected to the positive pole. The current is turned on very gently and from 1 to 8 milliamperes are applied for fifteen minutes. Through the same electrodes a rapid sinusoidal current, slowed to a rate of tolerance, is applied for eight minutes. The strength of the current should be such that the patient is just aware of flashes of light before his eyes. If the current is slowed too much, the patient may become faint. In case he complains of a blurry feeling in his eyes, the seance should be ended by a five-minute treatment with a double high-frequency vacuum electrode from the Oudin terminal. Treatment should be administered two or three times a week.

Electrosurgery of the Eye.—Ophthalmologists the world over have pointed to the possibilities of electrosurgery. The usefulness of electrodesiccation for the removal of warts, moles and cysts about the eyelids has been pointed out in Chapter XII. Trachomatous pannus and conjunctival lesions of trachoma have been successfully treated by electrocoagulation as well as by zinc ionization.

Monbrun and Casteran[16] advocate fine electrodesiccation for trichiasis and electrocoagulation for removal of cicatricial bands in the orbit which prevent the wearing of an artificial eye. They emphasize the advantage of destroying large tumors by coagulation through two active needle-point electrodes, which enable complete destruction of neoplastic tissues without the danger of extensive necrosis of adjacent bone.

In detachment of the retina an ingenious method of electrocoagulation was first proposed by Larsson.[12] He performed surface coagulation of the sclera with the object of producing an adhesive process in the choroid and retina which, in turn, should bring about reattachment of the retina. Jess[9] has shown in animal experiments a firm union of the retina to the choroid by Larsson's procedure. Weve[21] subsequently developed the micropuncture method, in which perforation of the sclera is done near the retinal tear, by a very fine needle-point electrode and coagulation through the puncture performed. In the United States Knapp[10] and Cottle[3] corroborated the successful application of this procedure.

Among other ingenious electrosurgical methods is that of Safar[20] who relieved stubborn cases of blepharospasm by first locating the branch of the facial nerve by the galvanic current and then partly destroying it through coagulation through the same needle.

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CHAPTER XXXVI

PHYSICAL THERAPY IN OFFICE PRACTICE

General Considerations. Planning the Treatment. Frequency of Treatments. The Treatment Habit. Judging Results. Selection of Apparatus. Office Space. Office Assistance.

General Considerations.—The employment of physical agents as an integral part of the practice of medicine has become firmly established during the past two decades. Their intelligent use is the best answer that scientific medicine can give to the cults, the chief stock-in-trade of most of these being the exploitation of some physical measures. Every practitioner of medicine can and should make use of physical measures in his daily practice. In order to be able to do so intelligently and consistently he must be familiar with the theory and practice of the principal physical methods in their application to general medicine and pathology. No physical agent should be employed by the physician unless he knows the source and nature of the physical energy and can predict the effects it will produce.

A good clinician will make a better physical therapist than the man who excels only in the knowledge of physics and machinery. The real physician will always choose from all available therapeutic measures, and will not neglect all for the sake of one in which he happens to be particularly interested. Seasoned experience and balanced judgment are needed to counteract the therapeutic enthusiast who exploits a single measure for a multitude of conditions.

The application of some form of physical treatment should be considered when in the opinion of the physician it will either serve as the primary method of treatment—ultraviolet in rickets, diathermy or fever therapy in gonorrheal arthritis, heat and massage in a traumatized joint—or else serve as an adjunct to other forms of medical and surgical treatment. As a basis of treatment the establishment of a definite diagnosis by all known methods is essential. Uncertain abdominal pain treated by diathermy has turned out to be cancer of the pancreas or chronic appendicitis; shooting pains down the leg treated by light therapy proved to be caused by a new growth in the spinal cord; a "bursitis" of the shoulder treated by massage and static sparks turned out to be a traumatic neuritis of the circumflex nerve with paralysis of the deltoid muscle, and so on. It may be somewhat easier to avoid pitfalls of diagnosis in one's own patients but it requires both knowledge and tact when a patient comes referred for physical therapy from a fellow physician. Stereotyped diagnosis, like neuritis, bursitis, chronic arthritis, lumbago, neurasthenia, on closer investigation may prove to be something entirely different. Another source of embarrassment is having patients referred with a statement that their condition is hopeless or functional only and that treatment is to be administered as a placebo.

The multitude of available physical measures raises the problem whether or not the medical profession can be so well taught the fundamentals of physical therapy in medical school and its application in hospital that future physicians can all make the most of such therapy. In other words can the general practitioner be expected to replace in large measure the specialist in physical therapy?

Irving[1] states that he cannot do so now because except here and there he has not been so trained. "At the present time the whole problem of more extended use of physical measures seems to call for team work of a kind that will recognize the elements of time consumption and convenience for doctor and patient alike, the overhead cost as distributed among the patients and finally closer concert between the practitioner and the specialist in physical therapy. Given every diagnostic analysis needed, there still is required judgment, which breadth of experience in administration alone, can give to devise the appropriate measures and to estimate frequency of treatment and length of continuance."

Planning Physical Treatment.—When planning physical treatment, the chief consideration should not be "Will a given apparatus fit a given diagnosis" but rather "Will in a given pathological condition in the individual a remedial agent or a combination of agents be of benefit?" It is not electricity in itself, but the thermal, mechanical and chemical effects of the various currents, that produce the desired therapeutic results. While in our mechanical age apparatus has become almost indispensable, physical therapy must not be necessarily identified with apparatotherapy. The relative value of the various remedial agents must be always taken into consideration, and the simpler methods not neglected for the complicated or spectacular ones.

In the average patient there are usually well-defined indications or contraindications for the application of remedial agents. If some form of electrotherapy or its combination with other physical agents is deemed best, the next step is to determine what technique is to be used and how often and how long it is to be applied. In other words, an exact prescription for electrotherapy has to be given just as in the case of prescribing drugs. To tell a patient that he should get some "electricity" is equivalent to telling him to get some "medicine." The records used in physical therapy clinics such as the New York Polyclinic Medical School and Hospital (shown in Chapter XXXVII) should enable the prescribing of the strength, duration and technique of application of each measure and the recording of each treatment. On the reverse side space is provided for a short history, physical examination, progress notes and time of discharge and the recording of the final result. For office use simpler forms may be employed.

Definite data put down on initial examination furnish the most desirable means of comparison for later examination. In traumatic conditions, for instance, one must note: (1) State of injury or repair, measurements, circumstance of limbs and joints, conditions and measurements of wounds and scars; (2) state of function, range of motion in joints, strength of individual muscles or groups of muscles (grip). Electrical tests of the response of muscles may furnish another definite record for subsequent comparison.

Frequency of Treatment.—Physical therapy ought to be administered as often as required by the exigencies of the condition. Acute and very painful conditions, as a rule, require daily treatments or even two or more per day. One designates as "bridging" those kept up just often enough, for instance, to relieve a painful condition. With improvement, the frequency can be reduced. For the average patient suffering from some chronic ailment treatment every other day is often sufficient and may be administered even less often, but this, of course, depends on the diagnosis and the progress noted.

Judging Results.—No treatment should be continued beyond a period of reasonable length if it is not bringing about visible improvement or relief of pain. Either the diagnosis must be wrong or the treatment inappropriate as to selection or technique if results are not forthcoming. It is impossible, of course, to make a general statement as to how soon results should be obtained, because it all depends on the individual condition. Patients very often will ask, "How long will I have to take these treatments?" In many instances the experienced physician will be able to give an approximate estimate, once he is thoroughly familiar with all the facts. If physical therapy is directed for the relief of pain it should effect improvement within a few treatments; if it is directed toward the increase of function results must be clinically measurable and demonstrable after a few weeks.

Both in the clinic and in the physician's office a definite procedure should be established to discharge patients and record the result. Treatment should be discontinued when on repeated examination no further improvement is found in the pathology or in the function of a diseased or injured part, or when, according to one's experience, further improvement ought to take place through the forces of natural recuperation. Often, however, it may be advisable to follow a successful course of treatments, directed toward the relief of local pathology, by a course of general restorative measures.

It is not often that the physician can claim to have "cured" a patient by remedial agents, for that would imply complete anatomical and functional restoration. In the practice of physical therapy we often learn to appreciate full functional recovery more often than a full anatomical one. A knee deformed by arthritis may never return to its normal contour, but as long as it is usable and does not pain we can state that "recovery is perfectly satisfactory." In chronic prostatitis there still may remain a palpable mass, but most of the inflammatory infiltration can be removed, the discharge and painful sensations stopped. One may state that "the condition is improved" if at least some of the principal symptoms or some of the pathological changes have been favorably influenced. "Maximum possible improvement attained" ought to be stated when the fullest amount of restoration has been achieved and no further physical therapy is indicated.

The Treatment Habit.—Certain chronic patients have a tendency to develop a "treatment habit," insisting on a certain line of treatment indefinitely. This is no doubt undesirable and should be discouraged. However, the other side of the picture should be considered also. If some form of physical treatment keeps a chronic sufferer comfortable and does not hold him back from other really indicated, sometimes vital, treatment it is perhaps a lesser evil to continue with such treatment, which serves both as a physical and as a moral support, than to let him drift. "The treatment habit" by physical methods is far less dangerous than by possibly habit-forming drugs.

Selection of Apparatus.—One of the most frequent questions asked of teachers in physical therapy is "What make of apparatus do you recommend?" The reply may be a counter question, "What make of automobile do you recommend?" and may be followed by the statement that apparatus built by manufacturers of good reputation and experience in the electromedical field and tested by physicians of clinics of standing is preferable to models volubly advertised by new sales concerns and endorsed by so-called experts whose names are unknown in scientific circles. The Council on Physical Medicine of the American Medical Association stands ready to pass upon specifications and therapeutic claims of all electromedical apparatus intended for the use of physicians. Apparatus accepted is produced by ethical manufacturers in accordance with engineering standards, it is tested in a clinic acceptable to the Council and therapeutic claims for the apparatus must be corroborated by definite evidence furnished to the Council.

The Council has repeatedly warned the profession as a whole against the acceptance of enthusiastic statements by manufacturers' agents—salesmen absolutely untrained in medical science. It is pointed out that while for the most part, the sales agents of manufacturers of physical therapeutic equipment are no less trained and no more overenthusiastic than the representatives of many drug and surgical supply houses, physicians should beware of the high pressure type of salesman of physical therapy equipment who extols his device in terms of its earning ability. Choice of such devices should be based solely on the decision as to their therapeutic efficiency.

If the prospective purchaser of any piece of equipment can bring himself to disregard argumentation of the sales firm emphasizing some special features in the apparatus in question, he should satisfy himself (1) that it is of standard type ("Council Accepted") and (2) that he can expect prompt service from the manufacturer or his authorized representative. Under the conditions of ordinary medical practice a piece of apparatus practically lasts a lifetime, and the only replacements ever needed are new bulbs or burners in phototherapy apparatus.

The installation of a modest layout for the principal electrotherapeutic measures can be had for less than $1000, and compared to the expense of a roentgen-ray outfit which, so far as general practice is concerned is of hardly any value for therapeutic purposes, a modest electrotherapeutic installation is a very useful and relatively inexpensive investment for the average medical man and will pay liberal returns during a lifetime, provided that its owner will devote himself to its proper study and use.

Office Space.—Even the most modest physician's office can be utilized to administer many forms of physical treatment. If the physician has only one room in which to see and to treat patients, one or two spaces, about 8 by 5 feet, can be screened or partitioned off and will hold one treatment table or cot and the apparatus and provide privacy. If there are two such spaces available one may contain a comfortable arm-chair or steamer chair in which patients can be treated in sitting position, with a comfortable support for the lower extremities. Providing electrical outlets for the attachment of apparatus is simple enough. One or two treatment-timers or automatic cut-off clocks should be used from the start to insure the methodical and efficient timing of treatments. Most busy practitioners, especially those caring for post-traumatic or compensation cases, find it of advantage to install physical therapy apparatus in a room adjoining their office.

An office which is to be used principally for physical therapy, demands special planning, not only because of numerous and often bulky pieces of apparatus, but, also, because the treatment time for the average patient amounts to about one hour. Besides the regular waiting and examination rooms, there must be at least one additional large room, subdivided into a number of treatment cubicles or a series of small individual treatment rooms. One large room housing all patients under treatment, yet allowing individual privacy, is preferable, because it allows the doctor or his technicians to be constantly within sight and sound of every patient. Also, it permits of switching or combining of apparatus with a minimum of time and effort.

FIG. 343.—Treatment cubicle.

Individual treatment cubicles should allow room for a treatment table or couch, space for some apparatus, a stool, and a small table or dresser. Room dimensions should be approximately 8 by 10 feet. Partitions between individual cubicles should be 6 feet high, to provide privacy and at the same time allow a maximum of light and air in each treatment space. Well-fitting curtains at the entrance of each space, allowing quick accessibility to patients and apparatus in case of any emergency, are preferable to doors.

Office Assistants.—It is, of course, advantageous if a physician can employ one or more skilled workers to assist him in the technical application of his treatments. However, many of the older physicians who are responsible for the present advanced status of physical therapy have never had any assistants. Indeed, they attribute their success to the fact that close observation of their patients has made them much more familiar with their condition, and has also made the patients more appreciative.

A physician beginning the practice of physical therapy had better give every treatment himself, for thus he learns to appreciate the importance of every technical detail. He should not hesitate to administer all physical treatment measures, including massage.

When his practice warrants the employment of a technician, the physician should make it a matter of invariable routine to inaugurate the treatment on each patient himself, and to be present for as much of the treatment time as possible. On subsequent visits he should see the patient each time he comes to the office and re-examine him at frequent intervals. Treatment of internal medical, gynecological or such other nature as require the physician's knowledge and technical skill, of course, must be attended by him at all times.

Many physicians well-versed in physical therapy prefer to train their own technicians. Naturally, a person who receives training in physical therapy after having had a grounding in anatomy, physiology, and pathology and the handling of the sick makes a better technician than the average office girl who has been merely taught how to turn on switches and put on electrodes. In hospital departments of physical therapy well-trained technicians are virtually indispensable. For further details on technical personnel see next chapter.

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CHAPTER XXXVII

PHYSICAL THERAPY IN INSTITUTIONAL PRACTICE

General Considerations. Relation to Other Departments. Director of Physical Therapy. Technicians. Location and Floor Space. Equipment, Records. Physical Therapy Books for Library.

General Considerations.—A physical therapy department is an integral part of every modern clinic and hospital and the number of hospitals still lacking such a department is steadily decreasing. A hospital survey of the Council on Medical Education showed in 1936 that 2008 or 31.7 per cent of hospitals in the United States have physical therapeutic departments. A survey of the hospitals of New York State in 1930 showed that 57 per cent possess a physical therapy department and 34 per cent of the remainder planned to organize one. It has been estimated that in a general hospital about one-fifth to one-quarter of the patients will be benefited by some form of physical treatment; in surgical, orthopedic and neurological hospitals about three-quarters of the patients will require physical treatment.

The American College of Surgeons[1] urges that all Class A hospitals should possess adequately manned and equipped physical therapy departments. It advises the observance of the following requirements as to the organization and management of a modern physical therapy service:

1. Hospitals carrying on physical therapy should have a well-organized department under competent supervision.

2. The department be properly planned and equipped in accordance with present-day standards.

3. There shall be adequate, trained personnel under competent supervision.

4. A comprehensive system of records be available in the department and filed in an accessible manner.

5. A definite procedure be established for the reception, treatment and discharge of the patient.

6. As far as possible there be periodic analysis of the work of the department to determine the results.

Relation to Other Departments.—The physical therapy department should be practically a reference department, like the roentgen-ray department. Patients referred there from other departments should have had the benefit of indicated diagnostic procedures beforehand and be treated in close coöperation with these departments. Cases may originate from the department itself only when special authority is vested in the director for this purpose.

Physicians referring patients to the physical therapy department, besides giving the diagnosis and possibly some salient facts, should indicate what is the object of physical treatment, such as "relief of pain," "restoration of function," "general tonic effect," etc. It is perfectly evident that suggestions as to the type of treatment should be welcome. The value of such suggestions will depend upon how much knowledge and practical experience the referring physician has in physical measures. In doubtful cases consultation is desirable.

Given a properly manned and equipped department, its first problem is not so much how to treat its patients as how to receive the type of cases which will most benefit by its work. Very often patients sent for physical treatment are referred much too late or should not have been sent there at all, whereas patients to whom properly applied measures should be of immeasurable benefit never receive them. Tactful missionary work by the director of the department is the only way to overcome by degrees such an undesirable state of affairs. The physical therapy department should not be made the dumping ground of chronic and incurable cases. Many conditions of fibrositis, adhesions, atrophy, ankylosis following inflammatory conditions could have been returned to useful activity by the early and intelligent use of physical measures promoting resorption and restoring function. In recent trauma the early use of physical measures for relief of pain and for the speeding-up of the process of repair is invaluable and can be applied without interfering with immobilization.

Much valuable time is wasted and much needless suffering is prolonged in hospitals which do not provide adequate physical measures at the bedside. In most modern hospitals the physical therapy department works as a unit for both in- and out-patients. Not only massage and therapeutic exercise, but all forms of electrotherapy, light therapy and hydrotherapy can be administered at the bedside with the many convenient and efficient types of portable apparatus now available.

Profiting from the experience of present-day military hospitals, there is also an increasing tendency to coördinate the work of the occupational therapy department with that of the physical therapy department under the same medical direction (Watkins[9]).

In order to stimulate interest in the work of the department, its director may hold scheduled clinics for visiting physicians, the staff and internes from time to time; it is also recommended that internes and nurses be given a number of lectures on the subject. The physical therapy department should be open for inspection at all working hours; consultation with other members of the staff, collaboration in clinical research with other departments all will tend to secure an understanding of the potential offerings of this indispensable department and secure the fullest coöperation of the other departments.

The Director of Physical Therapy.—The director of a department of physical therapeutics should be a physician who has had special training in this subject. The truism of a stream flowing no higher than its source applies with especial force to the physician in charge of a really efficient physical therapy service. Consulting daily with colleagues from any of the other hospital departments, and prepared to deal with a correspondingly large number of referred pathological conditions, his qualifications must be many-sided indeed. He should be preferably a Class A school graduate, and then have had best of all foundations, some years at least of general practice—this followed by thorough-going postgraduate courses, under recognized authorities, in physical therapy. Just as comprehensive training is needed for this activity as for neurology, surgery, orthopedics or any other special field of practice. Ideally he should be on a full-time paid status. The medical director, because of training, is the one to prescribe the patient's physical therapy and is responsible for its administration.

Consistency in ordering physical measures and in the working-out of a technique best suited to the needs of certain classes of cases and to the interests of the institution is only possible when *one* responsible medical man or department does all the prescribing and continues or supervises treatment until the limit of improvement according to his knowledge has been achieved. This does not preclude the constant observation of patients by the other members of the staff.

McEachern[6] reports that the American College of Surgeons advocates that the director of physical therapy be a member of the staff and have the same standing on the staff as any other specialist.

Under no circumstances should physical therapy be prescribed by others than physicians. During the years of early evolution of physical therapy some medical men, unable or too busy to study physical therapy, established departments by leaving the ordering and treatment wholly to the supposedly well-trained technician. It is a confession of ignorance and is certainly not serving the best interests of the patients or the proper development of physical therapeutics that there appear still to be some otherwise reputable institutions following this deplorable example. It is equally objectionable to place the department nominally in charge of a member of the staff who may be a good orthopedic surgeon or radiologist but wholly without comprehensive training along the broad field of physical medicine.

The duties of the director of a department are summarized by Coulter[2] as follows:

"1. To see all new cases, to prescribe for those in the clinic, and to prescribe for those in the hospital in consultation with the physician referring the case.

"2. To see all cases at least once every two weeks and to decide whether maximum improvement has been reached or whether treatment needs changing.

"3. To see cases at any time at the request of the technicians.

"4. To call the attention of the staff from time to time to certain treatments which might be helpful from the standpoint of physical therapy.

"5. To prepare and keep up by abstracts of literature a bibliography of physical therapy which will be available for members of the department and for the staff physicians of the hospital.

"6. To check with the chief technician and see that all directions are carried out faithfully, remembering always that these physical agents have high potential danger if handled carelessly.

"7. To do all in his power to make the department as truly scientific as possible and of real assistance to the members of the staff.

"8. To stimulate research among the younger members of the staff.

"9. To interest the physicians of the hospital in physical therapy, showing them the work being done in the fields in which they are interested.

"10. To organize a teaching program for the nurses, internes, technicians and physicians who might be interested in physical therapy.

"11. To prepare a schedule of places of interest in physical therapy for the visitation of technicians, each technician to have a half day every other month for this purpose.

"12. To check all equipment and supplies for the department of physical therapy. An accurate tabulation of all costs relative to material, repairs, help, supplies, etc., should be obtained at regular intervals from the central office of administration. This is necessary in order that the department may be put on a paying basis."

It is evident that *assistant physicians* and *internes* in the department should aid the director in his duties in as much as they are assigned to. It has been recommended that the interne on laboratory service be assigned to the physicial therapy department in addition to his other duties and this practice is also followed at the New York Polyclinic Hospital. The Council on Physical Medicine stated: "Most medical graduates devote about two years to hospital work before engaging in private practice. During this period they should receive broad practical experience in physical therapy. Internes should be encouraged to take an active interest in physical therapy during their incumbency and should be required at least to make themselves familiar with the procedures followed in every case coming under their care for which physical therapy is prescribed. Resident interneships or fellowships might well be established in physical therapy."

Technicians.—Properly trained technicians are indispensable for the carrying on of physical therapy in institutional work. The 1937 hospital survey of the Council on Medical Education and Hospitals states that 2382 "physical therapists" were reported by 1302 hospitals. The greatest number of physical therapists, 1648, appears to be serving in general hospitals. Other types of hospitals reported as follows: mental, 350; orthopedic, 167; tuberculosis, 62; children's, 41; and all other institutions, 114. The war time emergency has brought about training of a large number of technicians. The 1945 Hospital Service Report of the Council reports 3220 full time and 747 part time physical therapy technicians, a total of 3967. The estimated number of new graduates for 1945 is 904.

Coulter lists among the duties of the *chief technician* the following: "To direct the activities of the technicians; to see that all assistant aids are given proper division of responsibility and, with the doctor in charge, to outline a teaching program by which the technique shall be reviewed and the best methods obtainable instituted where advisable; to have all requisitions for equipment, supplies, etc., signed by herself, but where amounts are large to obtain the approval of the doctor in charge; to have any defects in machines or equipment reported immediately; to appoint one of the technicians in the clinic as assistant chief technician who shall assume the duties of the chief technician in her absence and who shall be responsible for certain activities of the clinic; to keep constantly on the alert and to call the attention of the physician in charge to anything of unusual interest; to keep the doctor in charge informed at all times concerning the arrival of new cases referred to the department; to encourage the making of criticisms and recommendations among the assistant aides."

As to the *technician* herself, McGuinness[7] states: "The nurse who studies physical therapy has a decided advantage over the ordinary technician. She has already learned the code of ethics as between the physician and herself and the patient and herself. Above all else she will be called upon to display tact, patience, forbearance, cheerfulness in greater measure than ever in her nursing career.

"Neatness, cleanliness, appropriate clothing and quietness of manner, voice, movements are as prime essentials as in the nurse. The patient will be quick to note if the technician be neatly and suitably dressed, washes her hands *before* as well as after the treatment, enters and moves about the room quickly and speaks in a low, modulated voice.

"A loud voice, a running comment of chatter especially on other cases, careless and noisy movements are more distasteful to the patient treated by a technician even than to one receiving nursing care. Especially is this so with the nervous, high-strung woman. Patients are only interested in themselves, *their* worries, troubles, illness or misfortunes usually are paramount. They have not the slightest concern in those of others, especially of other patients, the physician or technician. They feel their pay is not well earned if attention wanders from their immediate condition.

"Some patients wish to talk, to discuss symptoms, treatments, physicians, *their* peculiar case (every case is peculiar), the outcome, the length of time and number of treatments. The more nervous they are, the more they seem to have a compulsion neurosis to chatter. This must be discouraged. It is unwise to discuss these subjects, one is sure to be quoted, usually wrongly or adversely and trouble is likely to ensue, besides lack of benefit to the patient.

"The patient should be impressed by the physician that every physical measure calls for quiet and complete coöperation between the patient and technician. The latter should impress this by her manner and attention to the work on hand. Good work cannot be done if the mind is not upon it and the full measure of relief and relaxation will be wanting upon the completion of the treatment. The physician will notice this or be told about it and a new technician may be asked for.

"Do not tire the patient with too much, too long or too strenuous a treatment. Frequent rests are in order. Avoid fatigue. A quiet, relaxed patient will receive much greater benefit than a tense, irritable one. Overtreatment may have the opposite effect to relaxation and cause more nervousness. Nerves and muscles may be overstimulated or greatly fatigued to their disadvantage. In addition to the rests of one, two or three minutes required between exercises, there should be a prolonged one following the treatment as a whole, varying from fifteen to sixty minutes. If sleep can be induced so much the better.

"If the patient reports that she was so tired she could not find rest for hours after her treatment, this has been too long and too strenuous. Decrease the amount, increase the rest periods, be less vigorous. If cold or chilliness is complained of, especially of the feet, be sure these are treated first and then wrapped up to retain their warmth when possible. This will do more for the comfort of the patient than almost any other maneuver.

"See that the patient is in no danger of catching cold. Every new symptom will be ascribed to the treatment, colds will be blamed upon it and adverse effects because of it, will be related at great length. Therefore see that the patient is not in a perspiration. A weak patient should receive a light general massage with alcohol. A strong one may have a warm, then a cool shower with a vigorous massage.

"No treatment should last longer than forty-five minutes with rest interspersed. A weak patient should receive no longer than a fifteen-minute treatment with rests to begin with. The patient's reaction is the criterion.

Gradually lengthen the treatment in time and strength and keep rest periods according to the physician's orders and your best judgment.

"If the technician be in good health and properly trained, she should have no adverse effects from her work. Neuromuscular control is the prime essential of a good technician and next comes a sense of economy as to energy and time expended. No one can teach relaxation who is tense and nervous. No one can do good work whose muscles are strained after a treatment. No one can continue long in the profession who is easily fatigued.

"It is important, therefore, for the technician to guard health and strength, by getting the proper amount of sleep, food, rest, recreation, relaxation and exercise, quite as much as for the patient."

As to the training of technicians, the late Granger,[4] who did such outstanding work in organizing physical therapy services in the World War I period, stated: "Physical therapy technicians, still called in government service reconstruction aides in physiotherapy, basically should have had thorough grounding in anatomy, physiology, the analysis of muscle and joint motion and scientific massage. While a knowledge of electrophysiology and electrotherapeutic and hydrotherapeutic technique is desirable, yet it is not absolutely essential, as these subjects can be readily taught in any well-organized department of physical therapeutics. Graduates of schools of physical education or college graduates who have majored in physical education have in my experience made the best technicians. Nurses, though often good, have not, as a rule, had sufficient basic training. A well-trained technician is invaluable, not only in carrying out intelligently the treatments ordered but also in observing and reporting symptoms and the reactions of the patient to their physical therapeutic prescription. If the carrying-out of this procedure is insisted on the daily work becomes interesting and does not deteriorate into a mere mechanical routine."

The training and qualifications of technicians during the development period of modern physical therapy was in a somewhat chaotic condition in the United States, varying from those with college background and training in schools of physical education and in a few high class physical therapy schools to graduates of massage schools and of some downright commercial establishments even offering training by correspondence. It is evident that "graduates" of the latter type of schools had very poor educational background, very meager clinical training and at times total lack of such ethical standards as nurses possess.

Following a resolution passed by the House of Delegates of the American Medical Association in 1934, a program of standardization and classification of schools for physical therapy technicians has been successfully carried out by the coöperative effort of the Council on Physical Medicine and the Council on Medical Education and Hospitals. After inspection by the latter Council a list of approved schools for physical therapy technicians was published. Essentials of acceptable schools and lists containing complete data may be secured, on request to the office of the Council on Medical Education and Hospitals, 535 North Dearborn Street, Chicago.

In conjunction with the standardization of schools, an American Registry of Physical Therapy Technicians, located at 30 North Michigan Avenue, Chicago 2, has been established. Only those with acceptable training are included as members of the Registry. It provides two classes of certification: Technician and Junior Technician.

Location and Floor Space.—A physical therapy department can be started in one modest room with a few pieces of apparatus furnishing the basic forms of measures—heat, light, massage and exercise. With a capable physician at its head and a well-trained technician to carry out most of the clinical details, it will prove its worth very quickly. Any hospital, however, planning to make full use of modern physical therapy should anticipate future growth and provide ample room for its department. The question of space is quite a problem in old hospitals, where space is at a premium, and hence one often sees this department which should typify light and exercise crowded into a dark basement. The prime consideration

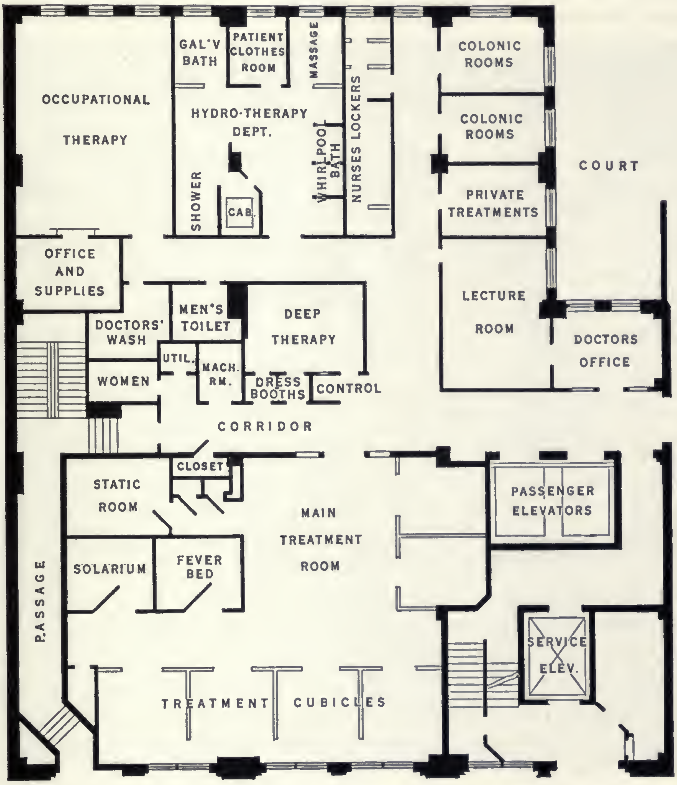

FIG. 344.—Floor plan of physical therapy department in New York Polyclinic Medical School and Hospital.

of locating the department should be easy accessibility to all parts of the hospital and clinic, near to the elevators, for patients will have to be brought to it for treatment and apparatus has to be taken to the wards and rooms. Location on the first floor is best and even the basement is not wholly undesirable, provided that the rooms are high and there is adequate light and ventilation.

In making use of the space at disposal it is generally preferable to arrange for one large general treatment room, where most electrical treatments and massage and active exercise are administered. Such a large room allows more economy of operation and better supervision and better ventilation than a number of small individual rooms. Separate rooms should be provided for hydrotherapy equipment, for a static machine and for gymnasium apparatus, if such is to be used. The large treatment room is conveniently subdivided into individual treatment cubicles by sheets suspended on wires or metal pipes, or else by wooden or steel partitions, 6 feet high, allowing ample space for circulation of air. The size of each of these cubicles should be 8 by 8 or 8 by 10 feet, allowing space for two treatment tables or cots and two pieces of apparatus. Two men or two women can thus be treated at the same time. If private patients are to be treated at the same hours, one or more separate smaller individual cubicles with substantial partitions can be provided for in the same or in an adjoining room.

Besides treatment rooms, there must be a waiting room or space for patients, an examination room for the physician, a dressing and rest room for the technicians, and sufficient closet space for linen and other supplies; if possible, also a store and repair room. In teaching clinics a small lecture room should be provided.

The total floor space for the department will depend on the average number of patients to be treated and the variety of equipment to be installed. A clinic expecting an average of from 25 to 50 patients' visits daily would require a total floor space of about 600 to 1000 square feet. Papers of Granger,[4] Grober,[5] Coulter[2] and the Council on Physical Therapy[3] contain details of the layout and equipment for clinics of various capacity.

Equipment.—A complete modern physical therapy clinic would consist of the following subdivisions: (1) Electrotherapy, (2) light therapy, (3) hydrotherapy and (4) mechanotherapy. Roentgen-ray therapy should not be carried under physical therapy, neither should the physical therapy department, as a rule, be made part of the roentgen-ray department except, possibly, in small hospitals.

Planning for the necessary equipment and the mode of its intallation should be left to the director of the clinic and not be planned for him by others. War-time physical therapy departments deal with a circumscribed number of conditions and, therefore, it is possible to specify a standard list of equipment. In general hospitals the number and types of apparatus, as well as the necessary and special accessories, will vary according to the prevailing type of work; a clinic dealing chiefly with traumatic cases will have different needs from that where largely pediatric or neuropsychiatric cases prevail. For the sum of from $2000 to $3000 a fairly complete equipment of the principal types of apparatus needed for electrotherapy and light therapy can be installed in a general hospital. A complete hydrotherapy and mechanotherapy equipment—the latter usually in the form of simple gymnasium type of apparatus—would about double the cost of initial installation.

The equipment of a small electrotherapy and light therapy department should consist of a few luminous heat and infrared radiators ranging from 150- to 250-watt capacity, two of 1500-watt capacity, two diathermy machines, one of these portable, a low-frequency (muscle stimulating) generator, a galvanic-faradic electrodiagnostic outfit, an air-cooled mercury vapor lamp or carbon arc lamp. The principal types of accessories, as described in Chapter IV, must also be provided. It may be well for the director of the department to ask for a blanket appropriation for accessories covering about double his initial needs, so that he may have no difficulty in securing extra items sure to be needed when the department gets well under way.

A model hydrotherapy room includes one control table with a shower bath, one electric light cabinet, two arm and one leg whirlpool baths, and one sitz bath. A 6-foot bathtub equipped for the administration of various treatments, may be added. In orthopædic hospitals therapeutic pools or large treatment tanks are essential.

A mechanotherapy room should include a set of gymnasium apparatus for active exercise, also a set of steel bars, a rowing machine, a nautical wheel, a creeping board, a few dumb-bells and Indian clubs and one foot-inversion treadle.

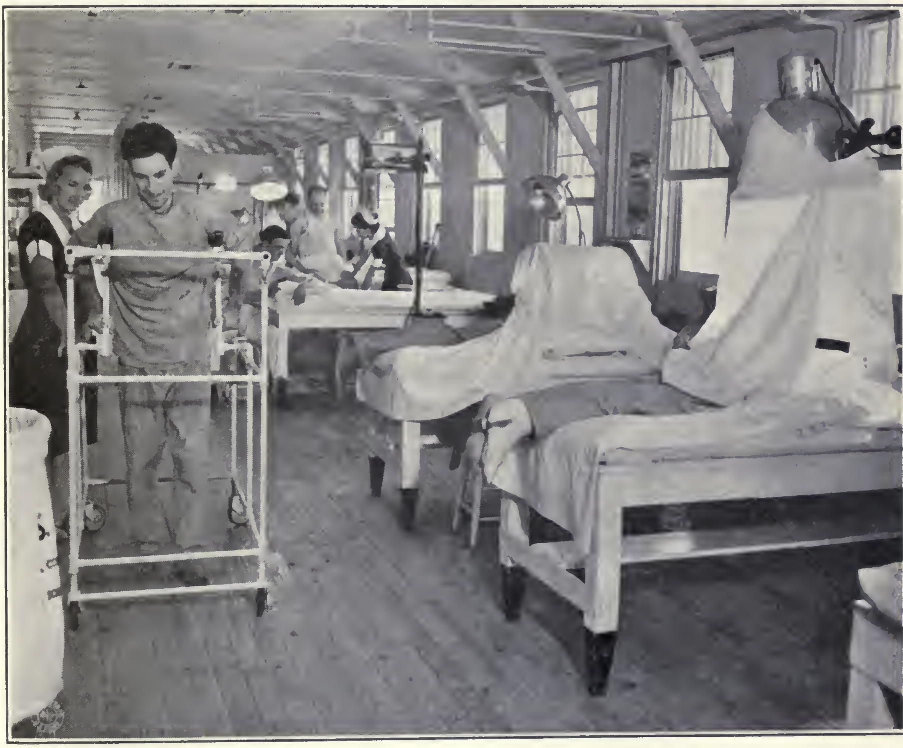

Fig. 345.—Military ward with physical therapy equipment. (Signal Corps, U. S. Army.)

All apparatus should be of standard type and purchased from manufacturers of good repute who will agree to furnish adequate service of periodic inspection and adjustments.

Details about current supply for apparatus and about current outlets have been presented in Chapter III.

Records.—Well-kept records are required for evaluation of results and for organized coöperation with the other departments of the hospital or clinic.

When a patient is referred to the physical therapy department it is desirable that his entire record, including roentgen-ray and laboratory findings, should accompany him. In hospitals where there is no unit history system the written order referring to patient should contain at least the diagnosis and the condition which is to receive special attention; it may also offer suggestions for the treatment. The physical therapy department may keep its own histories if there is no unit system in vogue.

The treatment record sheet or card is the most important document in the department. It should contain an exact order for the forms of treatment to be given, the sequence, duration, strength and details of technique of each, with a space for the signature of the administering technician. This is important for later check-up in cases of alleged accidents.

NEW YORK POLYCLINIC HOSPITAL

No............

PHYSICAL THERAPY RECORD

NAME.......... .... DIAGNOSIS...... ....

	Sequence	Part to be Treated	Distance or Strength	Time (minutes)	Dates of Treatment							
THERMAL		Infrared ...... watts Luminous ...... watts Whirlpool-Scotch douche Long wave diathermy Short wave diathermy Paraffin bath Fever treatment	in. in. { F. F. MA.									
PHOTO-CHEMICAL		Carbon arc Mercury arc	in. in.									
MECHANICAL		Massage (sed. stim.) Exercise (act. pass.)										
ELECTRO-MECHANICAL		Surging faradic Slow sinusoidal Static wave, sparks	cm. MA. in.									
HIGH-FREQUENCY		Monoterminal (Oudin) Autocondensation	MA									
ELECTRO-CHEMICAL		Galvanism Ion transfer Galvanic bath	MA. MA.									
SPECIAL		Muscle and nerve test Electrosurgery										

ELECTRODES Size....................

Position..................

NOTES:

Treatment Record at Polyclinic Hospital. Front Side

HISTORY AND PROGRESS

No........................ Admitted.......... ....

Name........................ Residence ....

Age...........Sex........... Nationality........ Color...........

History

Physical Examination

Progress Notes

Discharged.......................... Result..........................

Treatment Record (Reverse Side)

The physical findings at the time of admission should be carefully entered, in order to furnish definite comparisons for the checking-up of progress. The back of the regulation treatment record sheet is best suited for this purpose, as shown in the treatment chart used at the New York Polyclinic Hospital.

Regular progress notes must be made on the treatment record; patients coming daily should have such a notation entered at least once a week or whenever there is a definite change in the condition or in the treatment; patients coming every other day should have a note at least every two weeks and chronic cases at least once a month. Careful and systemic check-up of all patients by the director of the clinic is the only means to prevent patients continuing treatment indefinitely or without any apparent result.

A diagnosis card for cross-indexing of pathology is important for scientific check-up work.

A record book in the department should contain a list of patients treated each day, the classification of patients if there is any (clinic, ward, private, semiprivate, compensation), a marker for new patients, and possibly the name of the referring physician. This gives information at a glance of the amount of work going on.

Physical Therapy Library.—The Council on Medical Education and Hospitals enumerates the following books on physical medicine for the up-to-date hospital library in the May 19, 1945 issue of the *Journal of the American Medical Association:*

American Medical Association, Council on Physical Medicine: Handbook of Physical Medicine. $2. Am. Med. Assn., 1945.

Bierman, William: Medical Applications of the Short Wave Current, 2d ed. $5. Baltimore, Williams & Wilkins Company, 1942.

Glasser, Otto, and others (eds.): Medical Physics. $18. Year Book Pubs., 1944.

Kovács, Richard: Electrotherapy and Light Therapy, 4th ed. $8. Philadelphia, Lea & Febiger, 1942.

——— Manual of Physical Therapy, 3d ed. $3.25. Philadelphia, Lea & Febiger, 1944.

Krusen, Frank H.: Physical Medicine. $10. Philadelphia, W. B. Saunders Company, 1941.

——— Physical Therapy in Arthritis. $2.25. New York, Paul B. Hoeber, Inc., 1937.

Mennell, J. B.: Physical Treatment by Movement, Manipulation and Massage, 4th ed. $7. Philadelphia, P. Blakiston, 1940.

Mock, Harry E., Pemberton, Ralph, and Coulter, J. S. (eds.): Principles and Practice of Physical Therapy. In 3 volumes. $35. Hagerstown, Md., W. F. Prior Company, 1944.

Osborne, Stafford L., and Holmquest, H. J.: Technique of Electrotherapy and Its Physical and Physiological Basis. $7.50. Springfield, Ill., Charles C Thomas, 1944.

Wright, Rebekah: Hydrotherapy in Psychiatric Hospitals. $4. Boston, Tudor Press, Inc., 1940.

In addition, there are two physical therapy periodicals available:

Archives of Physical Medicine. (Official journal of the American Congress of Physical Medicine.) $5.00 yearly. 30 North Michigan Avenue, Chicago, Ill.

The British Journal of Physical Medicine and Industrial Hygiene. $5.00. 4–6 Bell Yard, Temple Bar WC.2, London, England.

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Appendix

Electrodiagnostic Charts and Tables

1. Tables of Motor Nerves and Muscles. 2. Charts of Motor Points.

Motor Nerves and Muscles of Face.

Motor nerves.	Branches.	Muscles.	Function.	Motor points.	Relative excitability.
Trigeminus (masticator) (5th)	....	....	Supplies all muscles of mastication	Above angle of jaw in front of lower part of ear	
		Masseter	Mastication	Same	1
		Temporalis	Mastication	Middle of temporal fossa	1
Facial (7th)	....	....	Supplies facial muscles	Immediately in front of tragus of ear	4
	Temporal (upper branch)	....	Supplies periorbital muscles	Lateral to outer angle of eye	2
		Frontalis	Raises eyebrows	Directly above eyebrow	1
		Orbicularis oculi	Sphincter action	Below outer angle of eye	2
		Corrugator supercilii	Draws eyebrows downward and medialward	Above the medial part of eye	1
	Buccal (middle branch)	....	Supplies muscles of nose and upper lip	Just below the zygoma	2
		Nasal compressor	Raises ala of nose	Middle of nasal septum	2
		Quadratus labii superioris	Elevates upper lip and carries it slightly forward	Between lateral angle of eye and angle of mouth	1
		Zygomaticus	Draws angle of mouth backward and upward	Below zygoma	2
		Orbicularis oris	Closes lips and causes them to protrude forward	Angle of mouth	2
	Mandibular (lower branch)	....	Supplies muscles of chin and lower lip	Slightly above and in front of angle of jaw	2
		Triangularis	Depresses angle of mouth	Below angle of mouth	2
		Quadratus labii inferioris	Draws lower lip downward and slightly lateral	Lateral to median line of chin	1

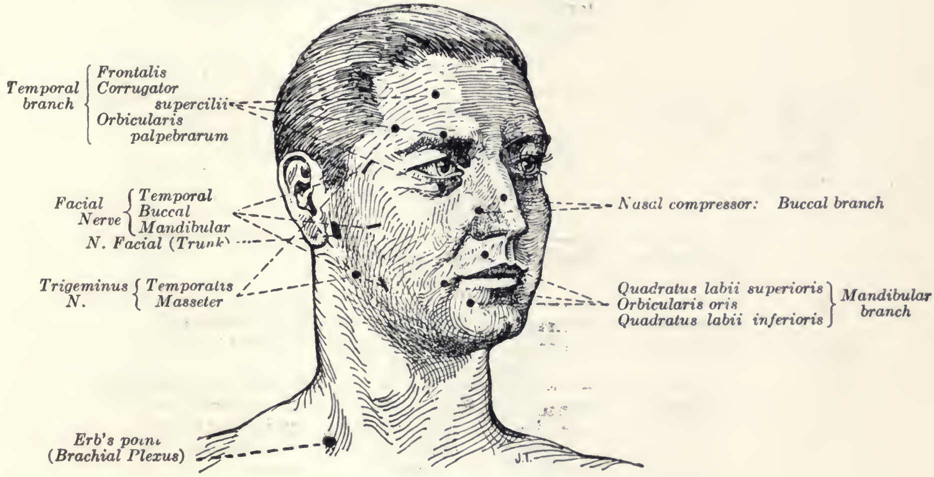

FIG. 346.—Motor points of face.

MOTOR NERVES AND MUSCLES OF ANTERIOR ASPECT OF TRUNK.

Motor nerves.	Branches.	Muscles.	Function.	Motor points.	Relative excitability.
Spinal accessory (11th cranial)	....	....	Supplies sterno-cleido-mastoid and upper trapezius		
	....	Sterno-cleido-mastoid	Lowers head to side and turns face to opposite side	Center of muscle	1
Brachial plexus (5th, 8th cervical)	....	....	Supplies muscles of upper extremity, some of scapular and pectoral muscles	Lateral to 5th, 6th, 7th, 8th vertebræ	4
	Circumflex	Deltoid	See upper extremity		
	Anterior thoracic	Pectoralis major	Draws the arm downward and forward	Just anterior and medial to axilla	1
	Posterior thoracic	Serratus anterior	Raises ribs in inspiration; draws scapula forward	Just anterior to midaxillary line —intercostal spaces	2
Dorsal nerves (1st lumbar)	....	....	Supplies muscles of thorax and abdomen		
	Intercostal ilio-inguinal ilio-hypogastric	External oblique	Compresses viscera and flexes thorax	On diagonal line from lowest rib to hip	3
		Rectus abdominis	Compresses abdomen and flexes thorax on pelvis	Middle of each muscular part	2

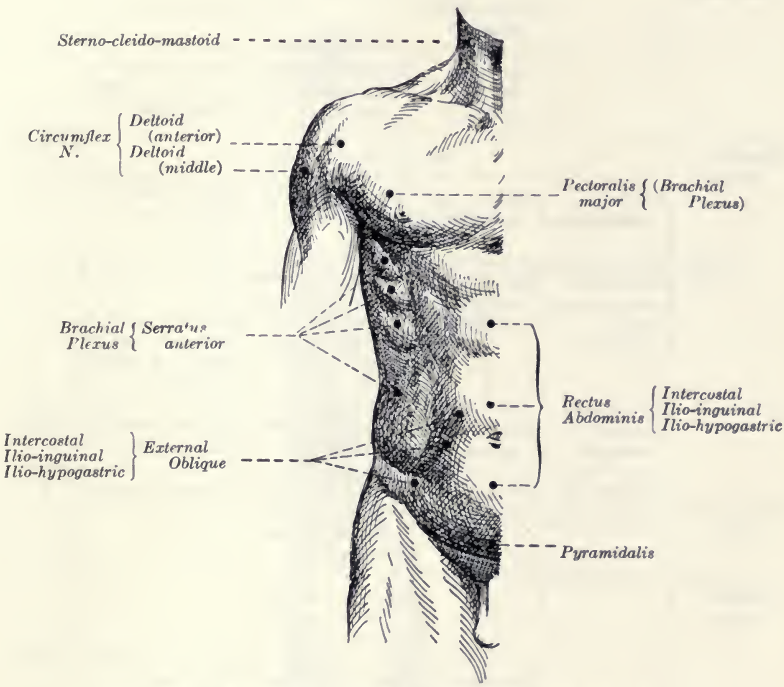

FIG. 347.—Motor points of anterior aspect of trunk.

Motor Nerves and Muscles of Posterior Aspect of Trunk.

Motor nerves.	Branches.	Muscles.	Function.	Motor points.	Relative excitability.
Spinal accessory		See	preceding page		
		Sterno-cleido-mastoid	See	preceding page	
		Trapezius (upper part)	Draws the head sideward and backward	Above the medial superior angle of scapula	1
Brachial plexus		See	preceding page		
	Supra-scapular	Supra-spinatus	Aids in raising arm sideward	Lateral part of supraspinous fossa	2
	Circumflex	Deltoid	See upper extre	mity	
	Long thoracic	Rhomboid	Elevates and adducts scapula	Between medial border of scapula and vertebral column	1
	Supra-scapular	Infra-spinatus	Rotates the arm outwardly	Middle of infra-spinous fossa	2
	Subscapular	Latissimus dorsi	Draws the arm downward and backward rotating it	At lateral border of muscle	2
Cervical plexus	....	....	Supplies a few muscles of thorax		
		Trapezius (middle and lower parts)	Draws scapula toward vertebral column; rotates scapula	Above spine of scapula; below medial angle of scapula	1
Thoracic and lumbar nerves		See	preceding page		
	....	External oblique	See	preceding page	
		Gluteals	See lower extremity		

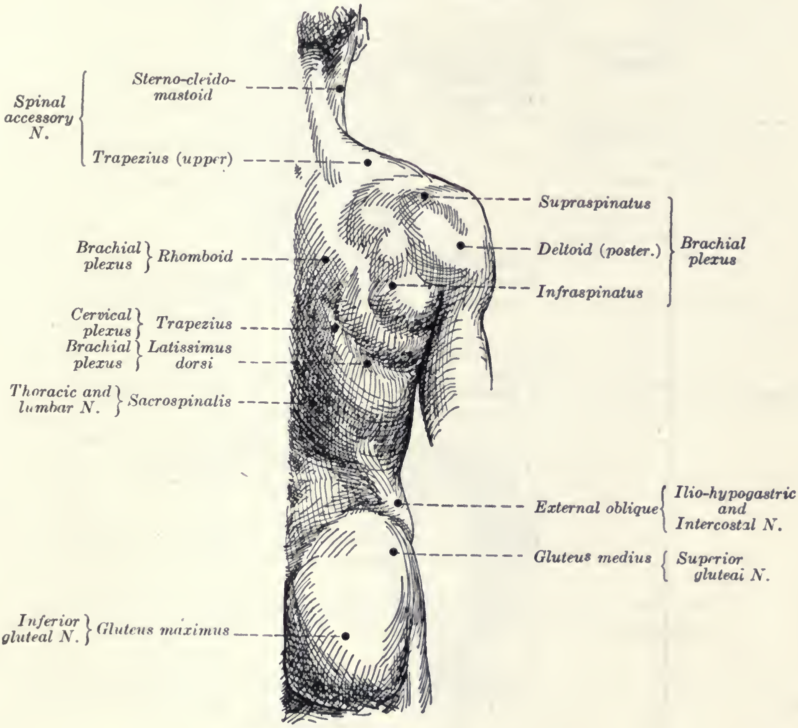

FIG. 348.—Motor points of posterior aspect of trunk.

MOTOR NERVES AND MUSCLES OF ANTERIOR ASPECT OF UPPER EXTREMITY.

Motor nerves.	Branches.	Muscles.	Function.	Motor points.	Relative excitability.
Brachial plexus (5th, 8th cervical muscle)	....	....	Supplies all muscles of upper extremity and some of scapular muscles	Lateral to 5th, 6th, 7th, 8th cervical vertebræ	4
	Circumflex	Deltoid	Flexes, abducts and extends arm	Center of bulk of each part (ant. middle & post.)	1
	Musculo-cutaneous	Biceps	Flexes and supinates forearm	Center of belly of muscle	1
		Brachialis	Flexes forearm	Medial to biceps lower part of arm	1
	Radial	Brachioradialis (supinator longus)	Supinates and aids in flexion of forearm	Just below outer condyle (anterior side)	1
	Ulnar nerve	....	Supplies some of hand, 4th and 5th fingers hypothenar eminence, small branch to the thumb	Anterior side of arm just above inner condyle and medial part of wrist	3
		Flexor carpi ulnaris	Flexes hand medialward	Anterior side of forearm, several cm. below inner condyle	1
		Flexor profundus digitorum	Flexes the distal phalanges of 4th and 5th fingers	Several cm. above hypothenar eminence	1
		Palmaris brevis	Corrugates skin of hypothenar eminence	Hypothenar eminence	3
		Abductor minimi digiti	Abducts little finger	Center of ulnar border of hand	2
		Flexor minimi digiti	Flexes little finger	Several cm. proximal to base of little finger	3
		Lumbricales III and IV	Adduction medialward of 4th and 5th fingers	Base of 4th and 5th fingers	3
		Dorsal interossei	Abduct fingers from each other	Between metacarpals	3
	Median nerve	....	Supplies most of flexors of hand and the thenar eminence	Just above elbow lateral to ulnar nerve and middle of wrist	2
		Pronator teres	Pronates forearm	Just below inner condyle	2
		Flexor sublimis digitorum	Flexes proximal phalanges of fingers	Middle of forearm, several cm. below the elbow	2
		Flexor carpi radialis	Flexes the hand laterally	Middle of forearm, midway between elbow and wrist	1

Motor nerves.	Branches.	Muscles.	Function.	Motor points.	Relative excitability.
		Palmaris longus	Helps to flex hand	Ulnar side of the forearm, midway between elbow and wrist	2
		Flexor profundus digitorum	Flexes the distal phalanges of 2d and 3d fingers	Middle of forearm several cm. above wrist	1
		Flexor longus pollicis	Flexes thumb	About 2 or 3 cm. proximal to base of thumb	1
		Abductor pollicis	Abducts thumb	Lateral border, base of thumb	3
		Flexor brevis pollicis	Flexes 1st phalanx of thumb, extends 2d	Base of medial border of thenar eminence	2
		Opponens pollicis	Flexes and adducts thumb	Center of thenar eminence	1
		Adductor pollicis	Adducts thumb	Between base of 2d finger and thumb	2
		Lumbricales I and II	Adducts 2d and 3d fingers medialward	Base of 2d and 3d fingers	3

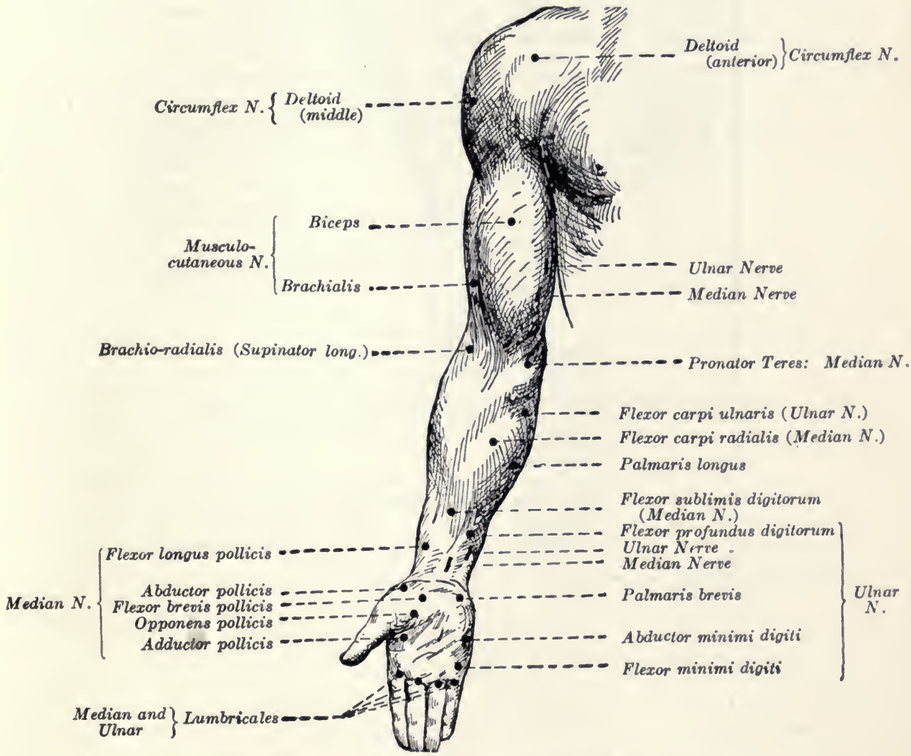

Fig. 349.—Motor points of anterior aspect of upper extremity.

MOTOR NERVES AND MUSCLES OF POSTERIOR ASPECT OF UPPER EXTREMITY.

Motor nerves.	Branches.	Muscles.	Function.	Motor points.	Relative excitability.
Brachial plexus		See	preceding page		
		Deltoid	See	preceding page	
	Radial nerve	....	Supplies extensors of forearm, hand, fingers	Posterior side of arm just above the elbow, radial side	3
		Triceps	Extends forearm	Two heads on medial border of muscle, other on the lateral border	2
		Extensor carpi radialis longus	Extends hand	Just below elbow, lateral side of forearm	2
		Extensor carpi ulnaris	Extends hand	Middle of forearm several cm. below elbow	2
		Extensor carpi radialis brevis	Extends hand	Several cm. below motor point of long extensor & slightly more to medial side	3
		Extensor communis digitorum	Extends fingers	Toward radial border midway between elbow and wrist	3
		Extensor indicis	Extends index finger	Middle of forearm lower $\frac{1}{3}$	3
		Extensor pollicis brevis	Extends thumb	Radial border several cm. above wrist	3
		Extensor longus pollicis	Extends thumb	Radial border of wrist base of 1st metacarpal	3

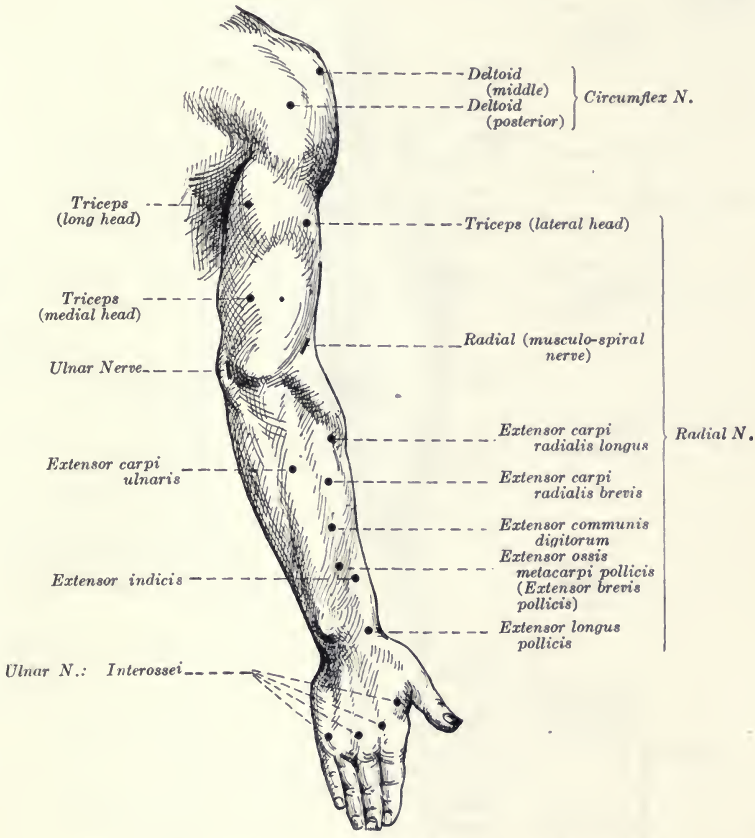

FIG. 350.—Motor points of posterior aspect of upper extremity.

Motor Nerves and Muscles of Anterior Aspect of Lower Extremity.

Motor nerves.	Branches.	Muscles.	Function.	Motor points.	Relative excitability.
Lumbo-sacral plexus	....	....	Supplies lower extremity		
	Femoral nerve	....	Supplies extensors of leg	Middle of groin	3
		Rectus femoris	Extends leg	Middle of thigh	1
		Vastus externus	Extends leg	4 to 5 cm. above knee, lateral border of thigh	1
		Vastus internus	Extends leg	Just above knee, medial border of thigh	1
	Anterior crural	Sartorius	Flexes thigh and leg, rotates the thigh outward and leg inward	Few cm. below groin in midline	3
		Pectineus	Flexes and adducts thigh	Just below groin medial border of thigh	3
	Obturator	Adductor longus	Adducts thigh	Medial border of thigh ⅓ distance from hip to knee	2
		Gracilis	Adducts thigh	Middle of medial border of thigh	2
	Common peroneal	....	Supplies extensors of foot and toes	Lateral to patella	1
		Tibialis anticus	Extends foot	Over head of the fibula	1
	Deep peroneal	Extensor digitorum longus	Extends toes	Lateral border of leg, just below knee	2
		Extensor hallucis longus	Extends big toe	Lateral to shaft of tibia midway between knee and ankle	3
		Extensor digitorum brevis	Extends toes	Anterior to lateral malleolus	3
		Interossei	Adduct 3 outer toes; extends slightly	Between metatarsal bones	3
	Superficial peroneal	Peroneus longus	Extends and abducts and everts foot	Along upper part of lateral border of leg	2
		Peroneus brevis	Extends and abducts foot	Lateral border of leg near ankle	3

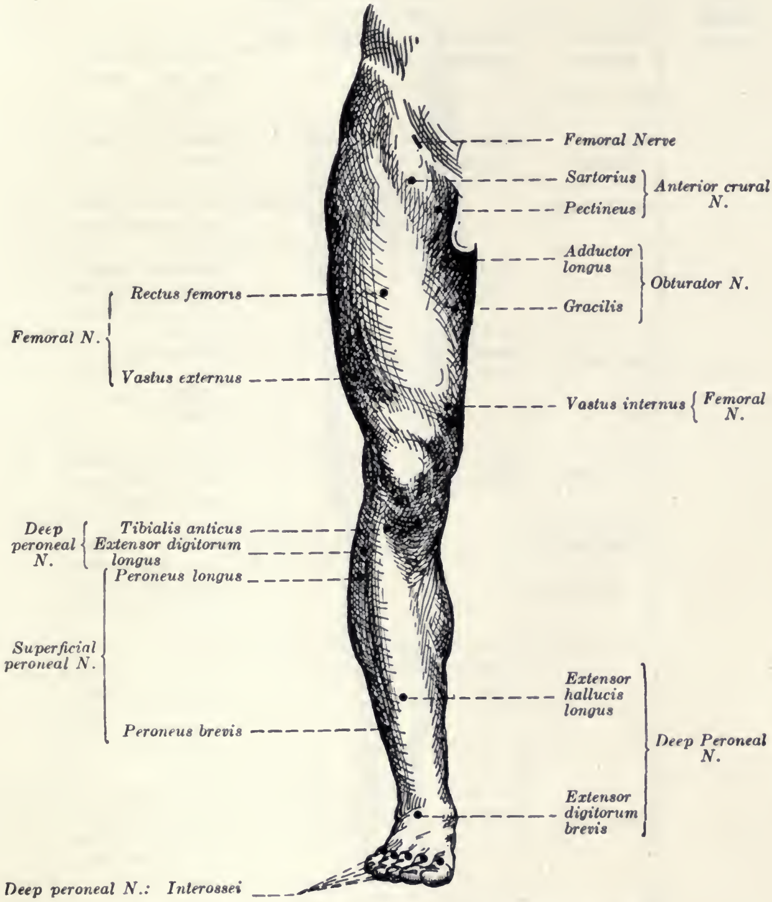

FIG. 351.—Motor points of anterior aspect of lower extremity.

Motor Nerves and Muscles of Posterior Aspect of Lower Extremity.

Motor nerves.	Branches.	Muscles.	Function.	Motor points.	Relative excitability.
Lumbo-sacral plexus		See	preceding page		
	Superior gluteal	Gluteus medius	Abducts thigh	Over lower part of muscle several cm. below iliac crest	2
	Inferior gluteal	Gluteus maximus	Extends thigh	Middle of buttock	.1
	Sciatic nerve	....	Supplies flexors of leg	Just below buttock in midline	3
		Semimembranosus	Flexes leg	Posterior medial border of thigh upper one-third	3
		Semitendinosus	Flexes leg	Post. medial border of thigh, middle one-third	3
		Biceps femoris	Flexes leg	Post. lateral border of thigh distal one-third	2
	Tibial nerve	....	Supplies flexors of foot and toes	Middle of popliteal space and just posterior to internal malleolus	2
		Gastrocnemius	Flexes foot	Lateral border at proximal part of muscle, medial border at distal part of muscle	1
		Soleus	Flexes foot	Lower one-third post. part of the leg toward lateral border	2
		Flexor digitorum	Flexes toes	Just above and posterior to internal malleolus	3
		Flexor hallucis	Flexes big toe	Just posterior to external malleolus	3

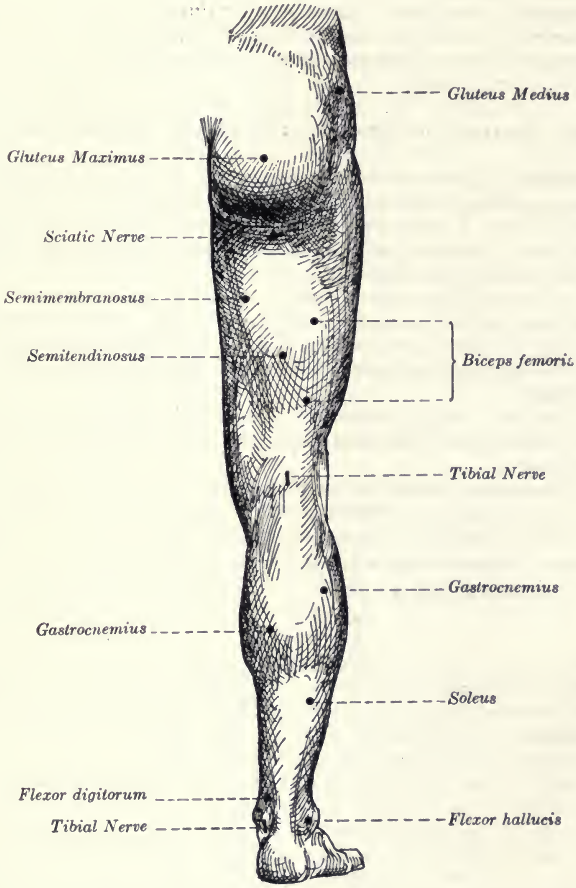

FIG. 352.—Motor points of posterior aspect of lower extremity.

GLOSSARY

PART I: ELECTROPHYSICS

Actinic. Pertaining to actinism. Capable of producing chemical changes as applied to radiant energy. Usually applied to radiant energy having this property.

Actinism. The property of radiant energy which produces chemical changes, as in photography or heliotherapy.

Actinometer. An instrument to measure the intensity of an actinic effect.

Actinotherapy. Treatment of disease by rays of light, especially actinic or chemical light.

Alternating current. A current which periodically flows in opposite directions.

Ammeter. An instrument calibrated to read in amperes the strength of a current flowing in a circuit. For medical purposes the ampere is too large a unit; hence, it is divided into a thousand parts or milliamperes. A meter calibrated to read in milliamperes is called a milliammeter.

Amperage. Strength of the electrical current expressed in amperes or milliamperes.

Ampere. The unit of the rate of transfer of electricity. The international ampere is the unvarying electrical current which, when passed through a solution of silver nitrate in accordance with certain specifications, deposits silver at the rate of 0.001118 gm. per second.

Amplifier. A device to magnify electric impulses, such as high-frequency currents. Its output is of greater amplitude than the energy which actuates it. It usually involves thermionic tubes.

Amplitude. The measure of the maximum deviation from zero to normal axis.

Anaphoresis. Transmission of electropositive bodies into the tissues by passage of electric current. The flow is toward the positive pole.

Angstrom. A unit of wave length of light. It is equal to $\frac{1}{10{,}000}$ micron.

1 Angstrom unit =	.000 1	(or 10^{-4})	microns
	.000 000 1	(or 10^{-7})	millimeters
	.000 000 01	(or 10^{-8})	centimeters
	.000 000 000 1	(or 10^{-10})	meters

Anelectrotonus. The state of diminished irritability of a nerve or muscle produced in the region near the anode during the passage of an electric current.

Angle of incidence. The angle between a ray incident on a surface and a line drawn perpendicular to the surface at the point of incidence.

Anion. See Ion. An ion carrying a negative charge. Since unlike forms of electricity attract each other, the anion is attracted by, and travels to, the positive anode. Examples are acid radicals and corresponding radicals of their salts.

Anode. The positive pole of an electrical device. In a thermionic tube, it is sometimes called the plate. When a positive potential is impressed on it from a battery or rectifier, the anode serves as a collector for the electrons emitted from the hot filament of the tube.

Anode current. The current passing between the anode and the cathode through the vacuous or partially evacuated space.

Anode voltage. The voltage between the anode and some specified point of the cathode.

Arc lamp. Source of light consisting of gaseous particles from the electrodes of an electric arc which are raised to a temperature of incandescence by an electric current.

Arc light. The light from glowing electrodes or luminous particles between two electrodes of carbon, tungsten or other material, when an electric current is applied and the electrodes separated a short distance.

Armamentarium. Outfit of a practitioner or institution, including books, instruments, medicine, and surgical supplies. (Obsolete.)

Atom. The smallest particle of an element that can exist alone or in combination with like atoms or other elements.

Autoconduction. A method, formerly much in vogue in France, of administering high-frequency currents. The patient stood or sat inside a large solenoid, the ends of which were connected to the two terminals of a high-frequency generator. The high-frequency current flowing through the solenoid generated a rapidly alternating magnetic field. This alternating magnetic field induced high-frequency currents in the patient.

Autotransformer. A transformer that has part of its turns common to both primary and secondary circuits. See Transformer.

Bases. Compounds of an alkaline character in solution, capable of reacting with acids to form salts and water; specifically the hydroxide of a positive element or radical.

Bias. The voltage impressed on the grid, relative to the cathode (filament), usually negative.

Bipolar. The use of two poles in electrotherapeutic treatments. When referring to an alternating current, biterminal should be used.

Biterminal. See Bipolar.

Booster. A device, consisting essentially of a small induction coil with adjustable core, for increasing the electromotive force of an alternating current circuit of a device such as a dynamo in series to increase the voltage of a direct current circuit.

Breakdown voltage. A critical value of voltage at which a discharge device such as a spark gap or a grid-glow tube begins to pass current.

Brush discharge. In electrotherapeutics, the discharge from a static machine (less commonly from a high-frequency apparatus), having a disruptoconvective character.

Capacitance. That property of a system of conductors and dielectrics which permits the storage of electric charges.

Capacitor. A device used primarily because it possesses the property of capacitance. It consists of two conducting surfaces separated by a non-conductor or dielectric. A condenser.

Capacity. Capacity, or capacitance, is a measure of the amount of electrical energy a condenser can store up.

Cataphoresis. The transmission of electronegative ions into the body tissues or through a membrane by use of an electric current.

Catelectrotonus. The state of increased excitability produced in a nerve current.

Cathode. The negative pole or electrode of any electrical device. In a thermionic or roentgen-ray tube it is often called the filament, and is an emitter of electrons.

Cathode current. The total current passing to or from the cathode through the vacuous space.

Characteristics. Dynamic characteristics of a tube are the values obtained with an alternating current voltage on the control grid under various conditions of direct current potentials in the electrodes. Amplification factor, plate resistance and mutual conductance are dynamic characteristics. Another characteristic frequently referred to as dynamic characteristic is the dynamic transfer characteristic, the characteristic of a tube combined with an optimum load in the plate circuit, reactive or resistance, and the control grid excited with accelerating current. The mutual characteristic shows the relation between grid voltage and plate current of a high-voltage amplifier. Static characteristics of a tube are the values obtained with different direct current potentials applied to the tube electrodes.

Choke coil. A coil having a large inductance, thereby introducing opposition to the flow of alternating current, or choking the current. The higher the frequency to the current which tries to flow, the greater the choking effect. There is no choking effect to direct current.

Chronaxie. Time intensity relation of electric stimuli. The minimal time for a current having twice the intensity of the rheobasic current.

Circuit breaker. A special switch, arranged to open a circuit quickly and automatically, without injury to itself, when the circuit is overloaded. The usual circuit breaker can be closed or opened by hand, as any switch.

Close coupling. The position in which two circuits or coils are placed in close magnetic proximity to each other, so that the transfer of energy from one to another is large.

Colloid. A substance which, when apparently dissolved in water or other liquid, diffuses not at all or very slowly through a membrane. Colloids are often gelatinous as albumen, gelatin, or starch. They generally resemble glue.

Commutator. A device for reversing the direction of an electric current; usually a segmental ring attached to a dynamo, on which brushes slide. Also similar hand-operated devices.

Condenser. A device for storing up electrical energy. It usually consists of conducting surfaces separated by an insulating medium called the dielectric. A capacitor is a condenser.

Conductance. The property of an electric circuit, or a body used as a part of that circuit, which determines, for a given potential difference between its terminals, the average rate at which electric energy is converted into heat. It is the reciprocal of resistance.

Conductive heat. An obsolete term applied to heat transferred by conduction from poultices, bags, etc.

Conductivity. The specific electric conducting ability of a substance.

Constant current. See Direct current.

Continuous current. See Direct current.

Continuous spectrum. An unbroken series of wave lengths, either visible or invisible. Such a spectrum is produced by light from incandescent solids, liquids or gases under high pressure passed through a prism. Also an unbroken range of radiations of different wave lengths in any portion of the invisible spectrum.

Convective discharges. Discharges from a high potential source in the form of visible or invisible streams of electrical energy passing through the air to the patient.

Convective heat. An obsolete term used to designate heat which is transferred by convection, as by a stream of air or water.

Conversive heat. An obsolete term used to designate heat generated in the tissues by a current of electricity or by radiant energy.

Cored carbons. See Impregnated carbons.

Coulomb. The quantity of electricity or the charge transmitted in one second by a current of 1 ampere. It is crudely analogous to the quantity of water, in gallons for instance, that flows into a container, or is stored in a tank.

Coupler. A device for the transfer of the energy of radio oscillations from one circuit to another, without a direct metallic connection, usually through an insulating medium.

Coupling. The amount of flux linkage of one circuit with another. It is a measure of the transfer of energy between two circuits.

Cycle. One period of alternating current, that is the complete change from zero to positive maximum, to zero, to negative maximum and back to zero.

Damped current. An oscillating current of electricity in which the amplitude of successive alternations become less and less until it finally dies away.

Damping. The steady diminution of the amplitude of successive vibrations, as of an electric wave or current.

Decrement. A measure of the degree of damping of a series of oscillations.

Desiccation. The process of drying up.

Diathermia. An inferior term for diathermy. See Diathermy.

Diathermy. The therapeutic use of a high-frequency current to generate heat within some part of the body.

Dielectric. An insulating substance that allows electrostatic induction to act across it, as the insulating medium between the plates of a condenser. An insulating or non-conducting material.

Diode. A thermionic tube containing two electrodes which pass current wholly or predominantly in one direction.

Direct current. A current that flows in one direction only. When used medically it is called the "galvanic" current.

Disruptive discharge. A passage of current through an insulating medium due to the breakdown of the medium under the electrostatic stress.

Disruptoconductive discharge. The static brush discharge that simulates both the convective effluve and the disruptive or spark-discharge.

Dry heat. In contradistinction to moist heat. Sources of dry heat are the hot water bottle, the electric heating pad, and radiant heat lamps of various types.

Effluve. A conductive discharge of a high potential current through a dielectric.

Electric circuit. The path through conductors by which an electric current passes.

Electricity. A form of energy which, when in motion, exhibits magnetic, chemical, mechanical and thermal effects and when at rest or in motion exerts a force on other electricity.

Electrify. To charge a body with electricity.

Electrocautery. An apparatus for cauterizing tissue, consisting of a holder containing a wire, which may be heated to a red or a white heat by a current of electricity, either direct or alternating.

Electrocoagulation. Coagulation of tissue by means of a high-frequency electric current. The heat producing the coagulation is generated within the tissue to be destroyed.

Electrocution. The destruction of life by means of electric current.

Electrode. A medium intervening between an electric conductor and the object to which the current is to be applied. In electrotherapy an electrode is an instrument with a point or a surface from which to discharge current to the body of a patient.

Electrodesiccation. The destructive drying of cells and tissue by means of short high-frequency electric sparks, in contradistinction to fulguration which is the destruction of tissue by means of long high-frequency electric sparks.

Electrodiagnosis. The determination of functional states of various organs and tissues according to their response to electrical stimulation.

Electrodynamometer. An instrument to measure the strength of an electric current, either alternating or direct, as by means of the interaction of two wire coils carrying the current.

Electrology. The branch of science that deals with the phenomena and properties of electricity.

Electrolysis. The electrical decomposition of a chemical compound. Examples: the separation of an electrolyte into its constituent parts by a direct current; the removal of hair by the electrolytic effect of a direct current.

Electrolyte. 1. A substance which in solution conducts an electric current and is decomposed by the passage of an electric current. 2. A solution which is a conductor of electricity.

Electrolyzer. Instrument for reducing stricture with electricity.

Electromagnetic induction. Generation of an electromotive force in an insulated conductor moving in an electromagnetic field, or in a fixed conductor in a moving magnetic field.

Electromotive force (abbreviation, E.M.F.). That effect of difference of potential which, on the closing of a circuit, causes a flow of electricity from one place to another, giving rise to an electric current. The strength of an electric current is directly proportional to the resistance in the case of direct current and to the impedance in the case of alternating current. Electromotive force is measured in volts or in some convenient multiple or fraction of a volt. Microvolt, millivolt and kilovolt are, respectively, one-millionth, one-thousandth volt and 1000 volts.

Electron. An extremely minute corpuscle or charge of negative electricity; the smallest that is known to exist. The dimension of the electron is estimated as:

$$10^{-13}, \text{ or } \frac{1}{10{,}000{,}000{,}000{,}000} \text{ centimeter.}$$

Electronic tube. A vacuum tube evacuated to such a degree that its electrical characteristics are due to electron emission.

Electrophoresis. See Phoresis.

Electrophorus. An instrument for obtaining static electricity by means of induction.

Electropyrexia. The use of electricity for production of fever.

Electrotherapist. A medical graduate who has had special training and has acquired skill in the therapeutic use of electricity. The term is sometimes used incorrectly to designate any one who administers electrical treatments.

Electrotherapy. Treatment of disease by means of electricity.

Electrothermotherapy. The production of heat within the living tissues for therapeutic purposes by means of bodily resistance to the passing of an electric current.

Electrotonic. Of or pertaining to electrotonus.

Electrotonus. The change in the irritability of a nerve or muscle during the passage of an electric current.

Endothermy. A term used as a synonym for surgical diathermy.

Epilation. Removal of hair.

Erythema. Active hyperemia of the skin indicated by abnormal redness.

Erythema dose. The amount of radiant energy sufficient to evoke perceptible redness of the skin.

Erythemogenic. Pertaining to erythema.

Ether. Hypothetic substance once regarded as permeating all space and capable of transmitting electromagnetic vibrations or waves. (Obsolete.)

Far ultraviolet radiation. Ultraviolet radiation of short-wave length; farthest away from the visible spectrum.

Farad. A unit of electrical capacity. The capacity of a capacitor which, charged with one coulomb, gives a difference of potential of 1 volt. This unit is so large that one-millionth part of it has been adopted as a practical unit called a microfarad.

Faradic current. An intermittent, alternating current induced in the secondary winding of an induction coil.

Faradism. The therapeutic use of an interrupted current to stimulate muscles and nerves. Such a current is derived from the secondary of an induction coil.

Filament. The cathode of a thermionic tube in which heat is supplied by current passing through it; also the incandescent element in luminous sources of heat.

Filter. A selective circuit network designed to pass freely currents within a continuous band or bands of frequencies, or direct current, and substantially reduce the amplitude of currents of undesired frequencies. In radiation therapy, screens or various substances which permit passage of some wave lengths while absorbing others.

Finsen lamp. A carbon arc lamp operating at 50 volts and 50 amperes so constructed that radiation is concentrated on an area 1 inch square; a water-cooled quartz system to remove infrared radiation and a compression quartz piece to dehematize the skin.

Fluorescence. Luminescence of a substance when acted on by short-wave ultraviolet radiation; usually ultraviolet.

Flux. The electromagnetic lines of force, or the magnetic field, produced by a current in a coil.

Fraunhofer's lines. Dark lines of a solar spectrum.

Frequency. The rate of oscillation or alternation in an alternating current circuit, in contradistinction to periodicity in the interruptions or regular variations of current in a direct current circuit. The frequency is computed on the basis of a complete cycle, a complete cycle being one in which the current rises from zero to a maximum, returns to zero, and rises to an opposite maximum and returns to zero again.

Frictional electricity. See Static electricity.

Fulguration. See Electrodesiccation.

Full-wave rectifier. A double element rectifier arranged so the current is allowed to pass in the same direction to the load circuit during each half cycle of the alternating current supply; one element functioning during one-half cycle and the other during next half cycle.

Fuse. A safety device comprising a strip of wire of easily fusible metal, the conductance of which is predetermined. The metal fuses and breaks the circuit when an excess of current passes through it.

Galvanic current. A steady unidirectional current.

Galvanism. Therapeutic use of direct current.

Galvanocautery. See Electrocautery.

Galvanometer. An instrument that measures current by electromagnetic action. It may consist of a magnetic needle delicately suspended in the center of a permanent coil of wire, or a suspended coil between the poles of a fixed magnet. When the current is applied to the coil, the needle is deflected over a calibrated scale. Galvanometers detect current and enable one to determine its direction, amperage and voltage. The d'Arsonval form is more common, in which a coil moves in a permanent magnetic field. The instrument is called a voltmeter when used in series with a high resistance to measure voltage; an ammeter when used across a shunt to measure amperage.

Gamma rays. Heterogenous electromagnetic vibrations caused by electronic disturbance in atoms of radioactive elements during their disintegration appear identical with roentgen-rays except that the wave lengths range from about 1.4 to 0.01 Angstrom.

Geissler tube. The original discharge tube for showing the luminous effects of discharges through rarified gases. The density of the gas in the tube is roughly one-thousandth that of atmospheric pressure.

Grenz rays. Roentgen-rays with an average wave length of 2 Angstroms (range from 1 to 3 Angstroms); obtained with peak voltage of less than 10 kilovolts. Synonym: over-soft *x*-rays.

Grid. An electrode having openings through which electrons or ions may pass. In a thermionic tube, it is generally placed between the cathode and the anode. Its potential controls the discharge between the cathode and anode (plate) in a predetermined manner without carrying any appreciable current itself.

Grid-glow device. A tube which passes no current until the voltage equals a critical value called the breakdown voltage.

Grid voltage. The voltage between a grid and a specified point of the cathode. See also Bias.

Grid voltage supply. The means for supplying and applying with proper regulation, the bias or a potential to the grid of a vacuum tube, which is usually negative with respect to the cathode.

Ground. An electrical connection with the earth, or with any conductor of large capacity.

Heliotherapy. The therapeutic application of radiation from the sun.

Henry. A unit of inductance. A circuit has an inductance of 1 henry when a current changing at the rate of 1 ampere per second produces a back electromotive force of 1 volt.

Hertzian waves. Electromagnetic vibrations that have wave lengths of 1 centimeter or longer.

High frequency. A current having a frequency of interruption or change of direction sufficiently high so that tetanic contractions are not set up when it is passed through living contractile tissues.

Homogeneous. Having the same nature or qualities of uniform character in all parts.

Hook-up. Used in speaking of the method of arranging circuits, appliances and electrodes in the giving of any particular treatment; as, for instance, the hook-up for direct sparks.

Hot-cathode tube. A vacuum tube in which the cathode is electrically heated (usually to incandescence) in order to increase the emission of electrons.

Hot wire meter. A type of meter used to measure the amperage of high-frequency circuits. The needle of the meter is connected to a wire having a known thermic expansion under the passage of a certain milliamperage and, as the wire expands, the needle moves across a calibrated scale until it indicates the amperage.

Hydroelectric bath. A bath in which electricity is administered to the tissues through water.

Impedance. A measure of the opposition to current flow. It may be caused by resistance, inductance, capacity or combination of these. The ratio of voltage to current flow in a circuit.

Inductance. The property of an electric circuit by virtue of which a varying current induces an electromotive force in that circuit or in a neighboring circuit.

Inductance coil. A device consisting of a cable containing a central conductor with heavy insulation used for electromagnetic field application in short wave diathermy.

Induction coil. A transformer with open magnetic circuit, excited by an interrupted or variable current.

Influence machine. A particular type of "static machine." Probably the only type used in physical therapy.

Infrared rays. Radiations just beyond the red end of the spectrum. Their wave lengths range between 7700 to 500,000 Angstroms. The therapeutic range extends from about 7700 to about 14,000 Angstroms.

Insulation. The state in which the communication of electricity to other bodies is prevented by the interposition of a non-conductor; also, the material or substance which insulates. The electrical resistance of an insulator is for convenience expressed in megohms, a unit representing a million ohms. Insulation may be also expressed in terms of dielectric value.

Insulator. A substance or body that interrupts the transmission of electricity to surrounding objects by conduction.

Intensity of electric field. The intensity of an electric field is measured by the force exerted on unit charge. Unit field intensity is the field which exerts the force of one dyne on unit positive charge.

Interrupted current. A current which is frequently opened and closed.

Interrupter. A mechanical or electrolytic device for making and breaking (closing and opening alternately) an electrical circuit. Such a device is ordinarily employed in low-voltage, direct current circuits.

Inverse square law. The intensity of radiation at any distance is inversely proportional to the square of the distance between the irradiated surface and a point source.

Invisible spectrum. Part of the spectrum, either below the red (infrared) or above the violet (ultraviolet), which is invisible to the eye.

Ion. One of the electrified particles consisting of an atom or group of atoms into which the molecules of an electrolyte are divided; or one of the electrified particles into which the molecules of a gas are divided by ultraviolet rays, gamma rays or roentgen-rays, or by other ionizing agents.

Ionic medication. See Ion transfer.

Ionization. The process by which neutral atoms or molecules become charged, either positively or negatively.

Iontophoresis. Synonym to Ion transfer.

Ion transfer. The introduction of chemical ions into the superficial tissues for medicinal purposes by means of a direct current. Iontophoresis.

Irradiation. Application of roentgen-rays, radium rays, ultraviolet rays or other radiation to a patient or object.

Joule. A unit of electrical energy equivalent to work expended when a current of 1 ampere flows for one second against a resistance of 1 ohm; a unit of work = 10,000,000 ergs.

Kilocycle. 1000 cycles.

Leyden jar. A glass jar coated partially, inside and out, with metal, or coated outside with metal and having salt solution inside. It is a capacitor.

Light. The sensation produced by electromagnetic radiation which falls on the retina. Radiant energy producing a sensation of luminosity on the retina limited to wave lengths from 4000 to 7000 Angstroms.

Light therapy. The therapeutic application of radiation in the visible spectrum; some include also, ultraviolet radiation.

Low frequency. An alternating current whose frequency in cycles per second is low. In general, low-frequency currents are attended by tetanic contraction when passed through the body.

Magnetic circuit. The closed path of magnetic lines; *e. g.*, the magnetic circuit of a transformer.

Magnetic field. The space permeated by the magnetic lines of force surrounding a permanent magnet or coil of wire carrying electric current.

Mains or main line. The conductors that deliver the current as it comes in from the street supply or from a motor-generator, if one is used.

Mechanical rectifier. A device which, by changing contacts at the proper moment in a cycle, changes alternating current into pulsating direct current.

Megohm. 1,000,000 ohms.

Meter. The unit of length in the metric system, largely used in European countries. Corresponds to 39.37 inches. An instrument or means for measuring some quantity, as a voltmeter.

Mho. The unit of conductivity; the reciprocal of ohm.

Micro. Prefix which means the millionth part. A micro-ampere is the millionth part of an ampere.

Microfarad. $\frac{1}{1,000,000}$ of a farad. A convenient division of the large unit.

Micron. The millionth part of a meter; the thousandth part of a millimeter; 1μ.

Milliammeter. See Ammeter.

Milliampere. One one-thousandth of 1 ampere.

Milliampere-minute. An electrical unit of quantity, equivalent to that delivered by 1 milliampere in one minute.

Millimicron. One-millionth of a millimeter; 1 m.

Modality. A modal character of, denoting a mode. In medicine it is a method of application or the employment of any therapeutic agent; limited usually to physical agents. The word is avoided by scholarly writers.

Molecule. A chemical combination of two or more atoms which form a specific chemical substance.

Monochromatic rays. Rays characterized by a definite wave length, as secondary rays.

Monochromator. A device designed for selective transmission of homogeneous radiant energy.

Monopolar. See Monoterminal.

Monoterminal. Use of one terminal only in the giving of treatments, the ground acting as the second terminal for the completion of the electrical circuit.

Morton wave current. An interrupted current obtained from a static machine.

Motor generator. A device consisting of a motor mechanically connected to a generator. Such machines are designed to generate direct current when alternating alone is available, or *vice versa.*

Non-conductor. A substance that will not conduct electricity. Strictly speaking, there is no perfect non-conductor. On the application of a sufficiently high voltage, current may be caused to flow through materials usually spoken of as non-conductors. See Insulator.

Ohm. The unit of resistance. The resistance that will allow 1 ampere of current to pass under the pressure due to an electromotive force of 1 volt.

Ohm's law. The law, determined experimentally by the physicist Ohm, which states that the strength of an electric current in a direct current circuit varies directly as the applied electromotive force, and inversely as the resistance of the circuit.

Open circuit. A circuit having some break in it so that current is not passing or cannot pass. The break may be intentional, as an open switch, or accidental, as a blown fuse, a loose connection or a broken wire.

Oscillating current. A current alternating, in direction, and of either constant or gradually decreasing amplitude. An oscillating current of constant amplitude is called an undamped current; one of gradually increasing amplitude, a damped current.

Oscillatory circuit. One which offers very little opposition to the establishment of an oscillating current of the frequency to which it is tuned.

Oscilloscope. An instrument for making visible the presence to the nature and form of oscillations or irregularities of an electric current.

Oudin current. A high-frequency current of higher voltage than the high-frequency currents used for long wave diathermy treatments.

Parallel connection. One in which the current divides and passes along more than one path.

Period. In an alternating current, the time required for one cycle to pass through a complete set of positive and negative values.

Periodicity. The rate of rise and fall or interruption of a unidirectional electric current.

Phoresis. The migration of ions through a membrane by the action of an electric current.

Phosphorescence. The induced luminescence that persists after cessation of the irradiation that caused it.

Photoluminescence. The light emission of an object which becomes luminescent when acted on by light.

Photometer. A device for measuring the intensity of light.

Photosynthesis. A chemical combination caused by the action of light.

Phototaxis. The movement of cells and micro-organisms under the influence of light.

Physiatrics. The science that relates to the medicinal and curative application of physical forces, as light, heat and electricity.

Physiatrist. The physician who practices physiatrics.

Physical therapist. A medical graduate skilled in physical therapy.

Physical therapy. Physical therapy is the therapeutic use of physical agents. It comprises the use of physical, chemical and other properties of heat, light, water, electricity, massage and exercise. See also Physiatrics.

Physical therapy technician or aide. A lay assistant trained to apply the physical measures of treatment which have been prescribed by a physician.

Plate. The positively charged plate-like element which collects the electrons emitted by the filament. A term commonly used for the anode.

Plate circuit. All the devices connected directly in the external circuit between the filament and the plate elements.

Polarity. 1. The fact or condition of having poles. 2. The exhibition of opposite effects at the two extremities.

Pole changing switch. A switch by which the polarity of a circuit may be reversed.

Positive rays. Streams of positively charged atoms traveling at high speed from the anode of a partially evacuated tube, under the influence of an applied voltage.

Potential. A condition by which current tends to flow from a place of higher to one of lower potential. The practical unit of measurement is the volt.

Potentiometer. An arrangement for securing any desired voltage by utilizing the voltage drop across a portion of current-carrying resistance.

Power. Rate at which work is being done. The electrical unit of power is the watt. See Watt.

Prescription carbons. See Therapeutic carbons.

Primary cell. A device consisting of a container, two solid conducting elements and an electrolyte, for the production of electric current by chemical energy.

Proton. The nucleus of the hydrogen atom. It is assumed to be the unit positive charge of electricity. See Electron.

Pulsating current. A current pulsating regularly in magnitude. As ordinarily used, applies to a unidirectional current.

Quantum. As much as; a certain specified quantity or amount; an elementary unit of energy; the supposed atom of light and other radiants, constant quantity or standard.

Quartz. Silicon dioxide, the principal ingredient of sandstone (crystallized silica; rock crystals). When crystal is clear and colorless it permits the passage of ultraviolet radiations in large proportions.

Quartz applicators. Quartz rods of various shapes and angles to conduct (by total internal reflection) ultraviolet radiation from a water-cooled mercury arc quartz lamp.

Quartz glass. Crystalline quartz is used for prisms and lenses, fused quartz for windows, etc., through which ultraviolet radiations are freely transmitted.

Quenched spark gap. One arranged and designed to put out, or quench, the spark very quickly. It is usually multiple with numerous electrodes about 0.3 mm. apart and equipped with a copper air-cooling device.

Radiant energy. That form of energy which is transmitted through space without the support of a sensible medium. Radio waves, infrared rays, visible rays, ultraviolet rays, roentgen-rays, gamma rays, and the recently discovered cosmic rays are energy in this form.

Radiation. A general term for any form of radiant energy, emission or divergence, as of energy in all directions from luminous bodies, roentgen-ray tubes, radioactive elements, fluorescent substances, or from an antenna.

Radio frequency. Currents of frequency above 10,000 cycles per second; currents of this frequency and higher are easily radiated by an antenna.

Radiotherapist. A physician who employs radiant energy for therapeutic purposes.

Radiotherapy. The treatment of disease by application of roentgen-rays, radium, ultraviolet and other radiations.

Rationale. A rational exposition of principles; the logical basis of a procedure.

Reactance. That component of impedance or opposition to flow of accelerating current, produced by capacitance or inductance. The ratio between the voltage and that component of the current which is 90 degrees out of phase with the voltage.

Rectifier. A device which converts alternating current into unidirectional current by virtue of a characteristic permitting appreciable flow of current in one direction only.

Refraction. The change of direction of a ray when it passes from one medium to another of a different density.

Regenerative circuit. An electron-tube circuit in which additional amplification is produced by feeding back some of the energy in the plate circuit into the grid circuit.

Relay. A device by which contacts in one circuit are operated by a change in conditions in the same circuit or in one or more associated circuits.

Resistance. The opposing influence of a body (solid, liquid or gaseous) to the passage of an electric current. It is expressed in ohms; 1 ohm of a pressure of 1 volt. The effect of the expenditure of electrical energy in resistance is to generate heat.

Resistivity. A measure of resitance or opposition to the flow of electricity. It is generally expressed in ohms per centimeter cube, *i. e.*, the resistance of a cube of 1 cm. on each side of the particular material.

Resonance. Two circuits are in resonance if they are in tune with each other; if the products of the inductance and capacity of each are equal.

Resonator. An electrical circuit in which oscillations of a certain frequency are set up by oscillations of the same frequency in another circuit. When this occurs, the circuits are said to be in syntony.

Rheobase. The voltage required for a minimal response with the make of the current in electric stimulation.

Rheophore. A cord connecting a patient to an electrical outfit. (Obsolete.)

Rheostat. A fixed or variable resistance for controlling the amount of current entering a circuit.

Rheotome. An interrupter with an adjustable speed control.

Ripple current. A pulsating current, superimposed on a direct current. The constant component is usually large relative to the sum of the amplitudes of the harmonic components.

Roentgen-rays. Radiation associated with the sudden change in velocity of free electrons (general radiation) or the transfer from higher to lower energy levels of electrons bound in atoms (characteristic radiation). "Roentgen-rays" is preferred by medical authorities, but "*x*-rays" is in more general use by physicists. The wave lengths concerned are usually between 0.005 and 1 millimicron or 0.05 to 10 Angstroms or 50 to 10,000 X units.

Roentgen-ray tube. A glass vacuum bulb containing two electrodes. Electrons are obtained either from gas in the tube or from a heated cathode. When suitable potential is applied, electrons travel at high velocity from cathode to anode, where they are suddenly arrested, giving rise to roentgen-rays.

Ruhmkorff coil. An apparatus consisting of two insulated coils, the primary consisting of a few turns of coarse wire, the secondary consisting of many turns of fine wire, enclosing a core of soft iron wires. The primary coil is connected with current supply and an interrupter. See Induction coil.

Schumann rays. Ultraviolet rays in the region bounded between 2000 and 1250 Angstroms.

Screens. See Filters.

Secondary. In a transformer, the output winding.

Secondary cell. Secondary cell is one which can be alternately charged and discharged. Hence it is reversible. See Primary cell.

Self-inductance. The property of an electric circuit which determines, for a given rate of change of current in the circuit, the electromotive force induced in the circuit itself.

Series. A mode of arranging the parts of a circuit by connecting them successively end to end to form a single path for the current. The parts so arranged are said to be "in series."

Series connection. One in which all of the current passes through each of the devices in succession, or one after the other.

Short circuit. An accidental overflow of current due to the establishment of a low resistance by-pass.

Shunt. When two or more electrical devices or resistance are so connected that the current is divided between them, the current through each device or resistance being inversely proportioned to the resistance, they are said to be connected "in shunt" parallel or multiple, with one another.

Sinusoidal current. Also see Alternating current. An alternating current following in the sine law and of such frequency as to afford the opportunity of separate (clonic) muscular contractions.

Solarium. A room designed for heliotherapy or for the application of artificial light.

Solenoid. A coil or series of turns of wire spaced equally between turns. Usually designates a coil whose length is greater than its diameter. When an electric current flows through a solenoid, the solenoid acts in general like a magnet.

Spark ball or Point electrode. An insulating handle having on one end a metallic ball or point. Used in giving static sparks.

Spark gaps. Arrangement of opposed points or surfaces, between which an electric spark may jump. An adjustable gap between needle points or between spheres is used to measure high potentials. For spark-over voltage see American Institute of Electrical Engineers Standardization Rules.

Spectrograph. An instrument designed to photograph spectrums on a sensitive photographic plate.

Spectrometer. A spectroscope so constructed that angular deviation of a ray of light produced by a prism or by a diffraction grating, thus indicating the wave length of the light, can be accurately measured.

Spectroscope. An instrument for separating radiant energy into its component frequencies or wave lengths by means of a prism or grating.

Spectroscopy. The branch of physical science that treats of the phenomena observed with the spectroscope, or those principles on which its action is based; also, the art of using the spectroscope.

Spectrum. Charted band of wave lengths of electromagnetic vibrations obtained by refraction and diffraction. The visible spectrum consists of the colors from red to violet. The invisible spectrum is composed of Hertzian rays, infrared rays, ultraviolet rays and roentgen-rays (x-rays), gamma rays and cosmic rays.

Static breeze. The brush discharge as used in therapy.

Static brush. See Static breeze.

Static electricity. Electricity produced by friction.

Static induced current. The charging and discharging current of a pair of Leyden jars or other condensers, the current of which is passed through a patient.

Static machine. Term applied to certain types of machine for producing high-tension direct current. Those used in physical therapy are influence machines.

Static wave current. The current resulting from the sudden periodic discharge from a patient who has been raised to a high potential by means of an electrostatic generator.

Step-down transformer. A transformer in which the number of turns of wire in the primary and secondary windings is in such relation as to reduce voltage. (See Transformer.)

Step-up transformer. A transformer in which the number of turns of wire in the primary and secondary windings is in such relation as to increase voltage. (See Transformer.)

Surgical diathermy. The use of high-frequency electrical oscillations in such a way that animal tissues are destroyed.

Tension. Sometimes used as a synonym for voltage; thus high tension would mean high voltage.

Tesla current. A high-frequency current having a voltage which is high, but intermediate between an Oudin and a d'Arsonval current. (Obsolete.)

Therapeutic carbons. Carbon electrodes cored or filled with various materials. When burning, they emit radiation containing various intensities and qualities of ultraviolet, visual and infrared energy.

Thermal. Pertaining to heat. Thermal unit = the amount of heat required to raise the temperature to a given mass of water 1° F. or C. Common thermal unit is the B.T.U., the heat required to raise 1 pound of water 1° F., and the Calorie, the amount of heat required to raise 1 gram of water 1° C. Thermal capacity; the amount of heat required to raise temperature of a body from 0° to 1° C.

Thermionic rectifier. A device that converts alternating current into direct current. It is an electric valve in which the electrons are supplied by a heated electrode.

Thermionic tube. A tube in which the electron emission is produced by the heating of an electrode.

Thermoelectric effect. The voltage effect generated at the terminals of a junction of two dissimilar metals; it is greater with some metals than with others.

Thermophile. A thermoelectric battery used in measuring small variations in the degree of heat. It consists of a number of dissimilar metallic plates connected together, in which, under the influence of heat, an electric current is produced.

Thermotherapy. The therapeutic application of heat.

Tickler. A coil in the plate circuit used to feed some of the energy back into the grid circuit.

Transformer. A device used for transferring electrical energy from one circuit to another, usually by magnetic field effect.

Tuned circuit. A circuit is said to be tuned when its natural period of oscillation is the same as that of some other circuit to which it is coupled.

Tuning. The operation of adjusting any circuit to be in electrical resonance with any other circuit or circuits.

Ultraviolet radiation. Radiation characterized by invisible rays in the electromagnetic spectrum between the violet rays and the roentgen-rays. In wave length it ranges from 4000 to 200 Angstroms. It possesses powerful actinic and chemical properties.
Undamped current. An alternating current of electricity in which the amplitude of successive alternations is maintained.
Unidirectional. The state of transmission in one direction as electric currents in a circuit.
Unipolar. See Monoterminal.
Uniterminal. See Monoterminal.
Uviol. Glass which is unusually transparent to ultraviolet rays.
Uviol lamp. An electric lamp with a globe of uviol glass.

Vacuum tube. A vessel of insulating material (usually glass) provided with metal electrodes, which has been so highly evacuated that the residual gas does not affect the current between the electrodes.
Valve tube. An electric valve consisting of a vacuum tube having for one electrode a hot filament.
Variable condenser. One whose electrical capacity may be changed or varied.
Variocoupler. A set of coils, generally so arranged as to make it possible to vary the coupling between different circuits.
Variometer. Two coils which may be placed in such relative positions that the inductance effects of each winding may be made to assist or practically neutralize each other.
Volt. The unit of electromotive force. The electrical pressure required to send a current of 1 ampere through the resistance of 1 ohm.
Voltage. Electromotive force or difference in potential expressed in volts.
Voltmeter. A meter designed and calibrated to measure voltage. Voltmeters are connected in parallel with the circuit or resistance over which the potential drop is to be measured.

Water-cooled quartz mercury vapor arc lamp. A small quartz mercury vapor arc lamp enclosed in a double-walled metal box with a quartz window for generation and application of ultraviolet rays. Water is circulated between the walls to conduct away the intense heat. Often called a Kromayer lamp after the inventor, Dr. E. Kromayer.
Watt. The unit of electrical power. The product of current and electromotive force.
Wattage. The power output or consumption of an electrical device expressed in watts.
Watt-hour. An electrical unit of work of energy. It is equal to the wattage multiplied by the time in hours. Its mechanical equivalent is 2655 foot-pounds.
Watt meter. A meter for measuring electric power.
Wave. A single impulse, or the disturbance included in a space of one wave length or the advance of a disturbance into a medium.
Wave length. The distance between corresponding points in two adjacent waves; *e. g.*, between two crests. In therapeutic radiations it is stated in Angstroms millimicrons.
Wave meter. A measuring device, arranged and calibrated to read the length of a radiated wave directly in meters.
Wave train. A series of waves, of the same or diminishing amplitude, usually repeating after intervals of inaction.
Wimshurst machine. A type of influence machine.
Wood's filter. A screen that absorbs visible rays but allows a portion of the ultraviolet rays to be transmitted.

X-rays. See Roentgen-rays.

PART II: MECHANOTHERAPY AND MUSCLE AND NERVE ACTION*

Abduction. A movement away from the mid-plane of the body.
Adduction. A movement towards the mid-plane of the body.
Afferent nerve fibres. Transmit impulses from various parts of the body to the brain or spinal cord.

* Courtesy of Dr. F. W. Ewerhardt.

All-or-none law. This states that when an individual muscle fibre is stimulated sufficiently to produce action, it contracts to its fullest extent. This applies to the motor unit only and not the entire muscle.
Amplitude. The total range through which a muscle joint functions.
Analgesia. Insensibility to pain.
Anatomical position. An erect standing position with the feet parallel and arms at the side with palms turned forward.
Anesthesia. Insensibility, especially to touch.
Antagonists. Those which oppose the prime mover.
Athetoid movements. Continuous, rhythmical, slow, worm-like movements which are always the same in the same patient and cease only during sleep.

Bone atrophy (or osteoporosis). Accompanies paralyses and disuse.

Central excitatory states. When afferent impulses enter the central nervous system they may elicit a sensation, a reflex response, a voluntary act, or any combination of these resultant activities. If the excitability of the synapse is increased it is known as central excitatory state. If the excitability is decreased, it is a central inhibitory state.
Circumduction. A term given to the combined movements of abduction, adduction, flexion, extension, rotation, so that the moving bone describes a cone-like figure with the apex at the joint, the base at its distal end.
Compression movements. Kneading, friction and pétrissage.
Contraction. Permanent adaptation of normal muscles to a newly acquired position without pathological changes.
Contracture. Permanent shortening of a muscle due to contraction of connective tissue and pathological changes of muscle fibres which persists even after the stimulus has ceased. Volkmann's contracture.

Dendrites and axons. Extensions of processes from the main body of the nerve cell.
Diplegia. A paralysis of any two extremities.
Dupuytren's contracture. A contraction of the palmar fascia. Etiology controversial.

Efferent nerve fibres. Transmit impulses from the brain and spinal cord outward to various special structures.
Effleurage. The use of the whole palmar surface of the hand to administer slow, longitudinal strokes. Pressure distinguishes superficial from deep effleurage.
End plate. The ending of a motor nerve fibre in a muscle.
Enteroceptive impulses. These arise in the viscera.
Epicritic sensations, Discriminative sensations. Fine or more exact sensations, as those evoked by cotton, wool and moderate temperatures.
Extension. The movement of straightening parts of the body in a sagittal plane.

Fascia. Connective tissue covering the outside of the muscle.
Fixation muscles. These maintain an extremity in a position appropriate for the performance of a particular movement by the agonists.
Flexion. The movements of bending parts of the body in sagittal plane.
Friction. The use of finger tips or thumb to move superficial tissue over subjacent structures.

Hemiplegia. A spastic paralysis of one lateral half of the body and extremities limited by the median line in front and in back.
Hypalgesia. Diminished sensibility to pain.
Hyperalgesia. Excessive sensibility to pain.
Hyperesthesia. Excessive sensibility.
Hypesthesia. Diminished tactile sense.

Inhibition. Under normal conditions muscular relaxation is brought about by an inhibition of a portion of the normal muscle tension. Contraction of a prime mover is accompanied by an inhibition of its antagonist, according to Sherrington's law of reciprocal innervation.

Kneading. The use of the palmar surface of the hand to administer rotary motion to compress the superficial tissues.
Kyphosis. Abnormal dorsal curvature of the spine.

Latent time. Period of delay between the application of a stimulus and the beginning of the muscular contraction.
Lordosis. Exaggerated lumbar curve, with increased convexity forward; sway back.
Lubricant. Cream, oil or talc applied to skin to facilitate a smooth stroke in massage.

Monoplegia. A paralysis of one extremity only.
Motor unit. A motor neuron, a nerve fibre and the 100 more or less muscle fibres in which the various branches of the axis terminate.
Movement. Various manipulations or strokes used to produce reflex or mechanical effects on soft tissue.
Muscle atrophy of disuse. This follows any prolonged immobilization.
Muscle rest. A state of action where the pressure is equal in both groups of muscles, sometimes called "zero position," and is not a state of inactivity.
Muscle tonus. A state of continuous contraction or tension of muscles accounted for by the fact that only a few motor units contract and do so in continual rotation.
Muscular atrophies. These result from a neural lesion, involving either the cell body or axon of the lower motor neuron.
Muscular dystrophies (or myopathies). These result from primary disease of the muscle itself.
Myostatic contraction. A condition of permanent shortening in a resting muscle which is maintained in the entire absence of nerve impulses.
Myotatic irritability. Muscle fibres freed of neural connections and inhibitions respond with increased activity to direct mechanical stimuli, such as tapping the muscle. This phenomenon is known as "myotatic irritability."

Paraplegia. A symmetrical paralysis of both lower extremities.
Paresthesia. Perverted sensation, as pins and needles.
Percussion movements. Tapotement.
Pétrissage. The use of one or both hands to pick up and wring soft tissue.
Phasic contraction. This is of brief duration and causes some displacement of a movable part. It is usually a voluntary act but may be purely reflex.
Plantar. Referring to the soles of the feet.
Postural tonus. This is determined primarily by proprioceptive reflexes which are confined largely to the muscles themselves.
Prime mover or agonists. Those whose contraction is essentially responsible for the movement of the part.
Pronation. Turning hand downward; rotating tarsal bones inward.
Prone. Lying with face downward.
Proprioceptive impulses. These arise in muscles, tendons and joints.
Proprioceptive reflexes. Confined largely to the muscles themselves.
Protopathic sensations, Affective sensations. Coarser or deeper sensations, as those responses to pain and extreme temperature.

Quadriplegia or Tetraplegia. A paralysis of all four extremities.

Reciprocal innervation. The process of maintaining relationship between two sets of stimuli.
Reflex arc. Simplest functional unit of the nervous system consisting of at least three neurons, afferent or sensory, efferent or motor and internuncial.
Rotation. The name given for the revolving movements of a part around its longitudinal axis.

Scoliosis. Lateral curvature of the spine.
Shaking. Gross vibration to an extremity or the whole body.
Spasm. Involuntary, continuous contraction of muscles. Hypertonicity.
Stretch reflex. A sudden stretch of a muscle which causes a reflex stimulation of the muscle by producing a quick contraction. Knee jerk.

Stroking movements. Superficial and deep effleurage.
Supination. The act of turning the hand upward; rotating the tarsal bones outward.
Supine. Lying with face upward.
Synapse. A connection by contiguity between dentrites of two neurons.
Synergists. Add and stabilize movements initiated and carried out by prime movers.

Tapotement. Use of relaxed fingers, palm or fist to administer a rhythmical series of blows.
Tonic contraction. This is usually a sustained contraction; it is almost always entirely reflex in nature and as a rule does not cause any motion.
Tonus. Tone or tonicity. Particularly, a condition of contractile tension in muscle which exists independently of voluntary innervation.
Tremor. Involuntary trembling or quivering movements.

Vibration. The use of the fingers or mechanical apparatus to administer light taps in rapid succession.
Vibratory movements. Vibration and shaking.
Volkmann's contracture. Contracture of fingers and sometimes wrist with loss of power due to impaired circulation of muscles of forearm.

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